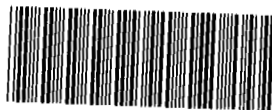000016432



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DRAFT FINAL

# PRELIMINARY ANALYSIS OF TREATMENT AND DISPOSAL OPTIONS FOR SOLAR PONDS WASTES

SOLAR EVAPORATION PONDS
ROCKY FLATS PLANT
(OPERABLE UNIT NO. 4)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

ADMIN RECCRD

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# EXECUTIVE SUMMARY

The Solar Evaporation Ponds (Solar Ponds) are located in the northeast portion of the Rocky Flats Plant (RFP) site on the northeast side of the Protected Area. The Solar Ponds were constructed primarily to store and treat by evaporation low level radioactive process wastes which also contained aluminum hydroxide, sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfate, hydrochloric acid, nitric acid, hexavalent chromium, and cyanide solutions. Low concentrations of solvents may also have been present as a minor constituent.

An effort has been underway since 1985 to close the Solar Ponds by concurrently evaporating the pond liquids and removing the pond sludges and sediments. The sludges and sediments removed from the ponds have been solidified to form a material referred to as pondcrete and have been stored in anticipation of transportation to and disposal at the Nevada Test Site or another approved offsite disposal facility. Waste removal and treatment activities conducted to date have resulted in removal of all waste liquid and sludge in Pond 207A and a small portion of the liquid and sludge in Pond 207C. Removal and treatment actions have not yet begun on the 207B series of ponds. The lack of a satisfactory offsite disposal facility and technical difficulties with the pondcreting operations have so far precluded transportation of the solidified sludges and sediments to a disposal facility.

The purpose of this report is to explore alternative waste treatment and disposal options that could be used to complete the desired closure of the Solar Ponds in-place. Included in this analysis is a consideration of potential alternatives to offsite disposal of the existing pondcrete that is stored at RFP. This report is not intended to satisfy the regulatory requirements of a Feasibility Study under the Comprehensive Environmental Response, Compensation and Liability Act or to constitute a Corrective Measures Study under the Resource Conservation and Recovery Act (RCRA). It should be viewed as a preliminary overview of technologies and combinations of technologies that have a high probability of applicability to Solar Ponds wastes.

Remedial activities at the Solar Ponds must be conducted in a complex regulatory environment of multiple laws, regulations, and enforcement authorities. In-place closure of the Solar Ponds would require, at a minimum, consideration of regulations promulgated under RCRA, CERCLA, NEPA, DOE orders, and various Colorado environmental laws. The complexity of this regulatory framework is exacerbated by proposed and anticipated changes to the regulations and by their modification through negotiation.

Of particular importance to the viability of in-place closure are proposed regulations relating to Corrective Action Management Units and hybrid closures. A hybrid closure coupled with application of the CAMU concept has the potential to significantly reduce the cost and logistical difficulty of remedial activities at the Solar Ponds.

Several waste treatment and disposal technologies could be used to close the Solar Ponds in place. For the most part, the described methods have a long history of application to hazardous waste sites and a variety of waste types. All have been successfully used at other

DOE facilities. All of them are capable of being designed to meet any risk-based or other performance criteria that may reasonably be applied. These technologies include the following:

De-nitrification. Nitrate and nitrite anions have been identified in the Pond 207C clarifier and all of the Solar Pond waters and sludges. Their presence is undesirable because of their contribution to instability in concrete and their toxicity. De-nitrification will increase pondcrete stability, decrease waste toxicity, and potentially reduce the volume of any solidified waste. Specific approaches to de-nitrification include bioremediation and electrochemical ion exchange.

Decanting/De-watering. For most treatment and disposal options, the water above the sludges will need to be decanted and treated separately unless it is needed for the selected treatment process. De-watering of the sludges is required to reduce the volume of sludge to be treated or to produce a treated product that will be dry enough to have desirable characteristics for bulk handling and placement in an existing pond or cell.

Sludge Washing. The high volume of Solar Ponds sludge and pondcrete contributes significantly to the potential cost and the difficulty of treatment and disposal. Sludge washing is a technology with the potential to concentrate contaminants in a residual sludge as a pretreatment step, facilitating the application of other remediation processes. However, the lack of detailed information concerning the sludge characteristics and chemistry creates considerable uncertainty with regard to this technology.

Solidification/Stabilization. Solidification may be required to immobilize the Solar Ponds waste and prevent the release of its contaminants into the environment. Solidification ideally produces a product characterized by low leachability, high thermal conductivity, high chemical stability over time, high resistance to breakdown by radiation, high mechanical stability, low corrosiveness, low volume, and low cost. Specific techniques include cementation and vitrification.

Barriers. Effective in-place closure of the Solar Ponds may require the inclusion of a vertical barrier to help control the flow of ground water beneath the Solar Ponds. Vertical barriers can be used to provide containment all around the Solar Ponds area or they can be placed upgradient and used to divert ground water around the ponds.

Liners. Some type of liner may be required for closure of the Solar Ponds. Liners are often an important element for in-place closure of wastes because they are a physical barrier which interrupts exposure pathways. The existing Solar Ponds have liners, but the effectiveness of those liners must be carefully evaluated if they are to be relied upon.

Caps. Some type of cap system placed above the treated sludges will likely be required for closure of the Solar Ponds. Like liner, the cap system is a physical barrier which will interrupt some exposure pathways. It will also decrease the mobility of contaminants by reducing the potential leaching of contaminants from the sludges.

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<u>Monitoring</u>. Following treatment and disposal of the Solar Ponds wastes, long-term monitoring of the disposal site will be necessary to demonstrate the absence of contaminant migration and to detect any failure of the disposal system. The monitoring options include both ground water monitoring and a variety of direct and indirect vadose zone monitoring techniques.

In-place closure of the Solar Ponds is clearly achievable from a technical standpoint. A number of treatment and disposal technologies are available for Solar Ponds wastes. In-place closure could be achieved through a sequence of steps involving de-nitrification, decanting of pond liquids and dewatering of the remaining sludges, evaporation of the water in Building 374, solidification of the sludges, replacement of the solidified sludge in re-lined Solar Ponds, capping the disposal cell, and long-term monitoring. Barriers may be required to maintain an adequate vadose zone. It may also be possible to incorporate and treat the existing pondcrete with the sludges.

Selection of a preferred alternative will require a detailed understanding of the Solar Ponds wastes, the extent of contamination of the Solar Pond liners and underlying soils, the site hydrogeology, and the regulatory environment. Currently, none of these are adequately characterized. However, it is possible to present an in-place closure option scenario consistent with reasonable technical and regulatory assumptions. The preferred option would include:

- In-situ de-nitrification;
- De-watering;
- Sludge removal;
- Ex-situ solidification;
- Re-lining of Pond 207A with FML;
- Disposal of Pond 207B stabilized sludge slurries in one portion of Pond 207A;
- Disposal of Pond 207C stabilized sludge slurry in the remaining portion of Pond 207A;
- Placement of a RCRA cap on Pond 207A;
- Monitoring of the vadose zone and ground water at Pond 207A; and
- Backfilling and capping the 207B ponds and Pond 207C.

It must be noted, however, that many details require further clarification before any specific recommendation can be made.

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# 1.0 INTRODUCTION

The Solar Evaporation Ponds (Solar Ponds) are located in the northeast portion of the Rocky Flats Plant (RFP) site on the northeast side of the Protected Area. The Solar Ponds lie within Operable Unit 4 (OU4) and Individual Hazardous Substance Site (IHSS) 101.

A map showing the location of the Solar Ponds, OU4, and IHSS 101 appears in Figure 1-1. Figure 1-1 also illustrates other features of OU4, within which the Solar Ponds lie. Appendix A contains a Historical Data Summary for the Solar Ponds.

The Solar Ponds were constructed primarily to store and treat by evaporation low level radioactive process wastes which also contained aluminum hydroxide, sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfate, hydrochloric acid, nitric acid, hexavalent chromium, and cyanide solutions. Low concentrations of solvents may also have been present as a minor constituent.

An effort has been underway since 1985 to close the Solar Ponds by concurrently evaporating the pond liquids and removing the pond sludges. The sludges removed from the ponds have been solidified to form a material referred to as pondcrete and have been stored in anticipation of transportation to and disposal at an approved offsite disposal facility or the Nevada Test Site. The Nevada Test Site is awaiting a permit to store mixed waste. Waste removal and treatment activities conducted to date have resulted in removal of all waste liquid and sludge in Pond 207A and a small portion of the liquid and sludge in Pond 207C. Removal and treatment actions have not yet begun on the 207B series of ponds. The lack of a satisfactory offsite disposal facility and technical difficulties with the pondcreting operations have so far precluded transportation of the solidified sludges and sediments to a disposal facility.

The purpose of this report is to explore alternative waste treatment and disposal options that could be used to complete the desired closure of the Solar Ponds in place. Included

in this analysis is a consideration of potential alternatives to offsite disposal of the existing pondcrete that is stored at RFP.

This report is not intended to satisfy the regulatory requirements of a feasibility study (FS) under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or to constitute a Corrective Measures Study (CMS) under the Resource Conservation and Recovery Act (RCRA). It should be viewed as a preliminary overview of technologies and combinations of technologies that have a high probability of applicability to the Solar Ponds wastes.

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## 2.0 BACKGROUND

The objective of this section is to briefly describe the Solar Ponds and to summarize significant studies and events relating to the Solar Ponds in order to understand the context in which this alternative analysis has been prepared. The following sections describe various aspects of the Solar Ponds, summarize the Solar Ponds Cleanout Program, and explain the status of the Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) program, which is required by the Interagency Agreement (IAG). Two recent documents providing greater detail on the Solar Ponds include the Final Phase I RFI/RI Work Plan (EG&G, 1992) and Technical Memorandum No. 1 to the Final Phase I RFI/RI Work Plan, Vadose Zone Investigation (U.S. DOE, December 1992).

Other reports containing useful information on the Solar Ponds include the 1988 Closure Plan (Rockwell, July 1988) and the Treatability Study Report and Process Formulator Report for Pond 207C and clarifier (Halliburton/NUS, July 1992).

### 2.1 SOLAR PONDS DESCRIPTION

The Solar Ponds were constructed to store and treat by evaporation a variety of radioactive and nonradioactive process wastes. Their use has changed with time as required by plant activities. This discussion includes the findings of numerous studies and reports, some of which have been completed quite recently. These studies have provided additional detail for portions of the history of the Solar Ponds that were either unknown or that were not fully understood when earlier documents were completed.

### 2.1.1 Original Solar Evaporation Pond and Earthen Lined Ponds

The Original Solar Pond, consisting of a clay-lined impoundment, was constructed in December 1953 in the vicinity of the existing Pond 207C. The Original Solar Pond was designated Pond 2. Construction of Pond 207A was already planned in the fall of 1955 for construction in 1956 when it became apparent that additional storage volume would be required for the winter of 1955/1956. Therefore, in September 1955 a second earthen pond was constructed to the southeast of Pond 2. This new pond was designated Pond 2-Auxiliary

and shared a common corner with Pond 2. Pond 2-Auxiliary was originally unlined, but was later lined with clay. Routine use of Ponds 2 and 2-Auxiliary ceased in August 1956 when Solar Pond 2A (later designated Pond 207A) entered service; but limited use of Ponds 2 and 2-Auxiliary continued into the early 1960s. A third earthen pond was constructed in April 1959 in support of de-nitrification experiments pertinent to the Solar Ponds. This third cell was immediately east of Pond 2, and the third earthen pond essentially covered the same areal location that Pond 207C later occupied. The de-nitrification experiments continued unsuccessfully until the fall of 1959. Pond 2-Auxiliary was removed, and the area was regraded in September 1962 in anticipation of the construction of Building 779. Analyses of soil from the bottom of Pond 2-Auxiliary showed 11,000 to 75,000 disintegrations per minute per kilogram (dpm/kg) of radioactive contamination. Contaminated soil from Pond 2-Auxiliary was placed in one of the East Trenches on the RFP site. Pond 2 and the third earthen pond remained in place until 1969 when the area was regraded in preparation for construction of Pond 207C. Although use of Ponds 2 and 2-Auxiliary ceased in the early 1960s, photographs exist of the ponds after that time in which water can be seen in the ponds. It is believed that the water observed in these ponds was probably due to incident precipitation rather than due to the placement of waste in the ponds.

## 2.1.2 Pond 207A

Pond 207A was placed into service in August 1956. The initial construction of this pond included a liner consisting of asphalt planking approximately 1/2-inch thick. Pond 207A is approximately 250 feet by 525 feet at the crest. Pond 207A and the other ponds were operated with a minimum freeboard of 2 feet. At its maximum allowable level, the pond's liquid covers an area of approximately 230 feet by 505 feet. This corresponds to a surface area of approximately 116,200 square feet, or approximately 3.0 acres. The maximum operating depth is approximately 7.5 feet.

Pond 207A was redesigned in November 1963. At that time, the asphalt planking was replaced with asphaltic concrete, and the slopes of the pond bottom and the pond sides were significantly modified. As a result of these modifications, the bottom slope of the pond drained to a sump at the northeast end of the pond.

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The side slopes of Pond 207A were relined in the fall of 1988 as a part of closure activities. The relining consisted of a minimum of 1/8-inch thick, rubberized, crack-sealing material, laid over the side slopes of the pond. This relining was performed to minimize leakage from the pond in preparation for the transfer of pumped-back ground water for evaporation.

### 2.1.3 Ponds 207B-North, Center, and South

Solar Ponds 207B-North, Center, and South were placed in service in June 1960. These ponds were also originally lined with asphalt planking. Based upon available records, it appears that the 207B ponds were relined shortly after being placed into service. The asphalt planking was covered with asphaltic concrete at 207B-South in November 1960, and at 207B-North and Center in August 1961.

Ponds 207B-North, Center, and South are approximately 180 feet by 253 feet at the crest. At their maximum allowable level, the ponds' liquids cover areas of approximately 175 feet by 245 feet. This corresponds to a surface area of approximately 42,900 square feet each, or approximately 1 acre. Ponds 207B-North and Center have maximum operating depths of approximately 6.5 feet. Pond 207B-South has a maximum operating depth of approximately 5.5 feet.

In 1977, the 207B ponds were relined as a portion of a water management plan which was implemented at RFP. Prior to relining, the linings of Ponds 207B-Center and South were removed, bagged, cemented, and disposed offsite. The lining of Pond 207B-North was not removed because it had held a minimal amount of sludge, and residual radioactivity levels were not elevated. All of the 207B ponds were then relined, and Pond 207B-South received a synthetic Hypalon liner 45 millimeters thick. This pond was also provided with a leak detection system between the Hypalon liner and the asphaltic concrete liner.

### 2.1.4 Pond 207C and Clarifier

As previously discussed, Pond 207C was constructed in approximately the same locations as the Original Solar Pond and the third earthen pond. Pond 207C was placed into service in December 1970, and has an asphaltic concrete liner. It is believed that Pond 207C has not

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been relined since construction. The bottom of Pond 207C slopes to the northeast and was provided with a leak detection system. Pond 207C is approximately 160 feet by 250 feet at the crest. At its maximum allowable level, the pond's liquid covers an area of approximately 155 feet by 245 feet. This corresponds to a surface area of 38,000 square feet, or 0.87 acre. The pond has a depth of approximately 7 feet.

The clarifier is a 25-foot diameter tank located between Pond 207A and Pond 207C. The clarifier was used in the previous pond cleanout to thicken pond sludge prior to mixing with cement. The clarifier tank contains approximately 27,000 gallons of sludge and water derived from Pond 207A. This material was placed in the clarifier when the pond sludge was being treated to generate pondcrete.

### 2.1.5 Side Berm Repairs

Engineering records indicate that the exposed portions of the berms at the Solar Ponds have been repaired and relined a number of times. These repairs were made because of cracks and damage that were identified in the exposed lining material. In April 1967, an unsuccessful attempt was made to fill the cracks on the side walls of Pond 207B-North with mastic. In November 1967, side wall cracks in Pond 207B-North were successfully repaired with burlap and asphalt. In October 1968, Pond 207B-Center had its side walls successfully repaired with burlap and asphalt covering, and an additional coat of asphalt was applied to Ponds 207B-North and 207B-Center. Also, the side walls of Pond 207B-South were covered with burlap and asphalt in September 1970. The side walls of Ponds 207B-North and Center were covered with Petro-mat and hydraulic sealant in October 1971. The side walls and bottoms of Ponds 207B-South and 207B-North were relined with Petro-mat and hydraulic sealant in October 1972 and September 1973, respectively.

### 2.1.6 Trenches and Sumps

Six interceptor trenches were constructed north of the Solar Ponds to minimize natural seepage and pond leakage that might otherwise enter North Walnut Creek. This seepage and leakage contributed to elevated nitrate levels in the creek.

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Trenches 1 and 2 were installed in October 1971, Trench 3 in September 1972, Trenches 4 and 5 in April 1974, and Trench 6 in July 1974. Trench 5 drained by gravity to Trench 4. Water from Trench 4 was pumped to Trench 3, and Trench 3 returned the water to Pond 207A. Trenches 1 and 2 pumped water uphill into sumps, after which the water was returned to Ponds 207B-North and 207A. This system of trenches was largely successful in minimizing nitrate levels in North Walnut Creek.

The trenches were in operation until the early 1980s when they were replaced by a more extensive Interceptor Trench System (ITS). The trenches and sumps that were not destroyed in related construction were abandoned in-place.

## 2.1.7 Interceptor Trench System

The ITS was installed as a part of the construction of the Perimeter Secured Zone at RFP. This construction destroyed some of the existing trenches, so a more extensive ground water and seepage collection system was designed and constructed. Again, the purpose of the system was to minimize the seepage of waters into North Walnut Creek. The depths of the ITS range from approximately 1 to 27 feet below the ground surface, with typical depths of 4 to 16 feet.

Liquid collected in the ITS flows by gravity to the interceptor trench pump house. The liquid from the pump house is then pumped to Pond 207B-North. The current amount of seepage collected by the ITS is estimated to be approximately 4 million gallons per year.

## 2.1.8 Historical Use

The Solar Ponds were constructed primarily to store and treat by evaporation low-level radioactive process wastes containing high concentrations of nitrate and treated acidic wastes containing aluminum hydroxide. During their use, these ponds are known to have received additional wastes such as sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfate, hydrochloric acid, hexavalent chromium, and cyanide solutions. Solvents and other organics have not been routinely

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discharged to the ponds. However, low concentrations of solvents may have been present as a minor constituent in other aqueous wastes.

The use of the 207B ponds changed in 1977. Until then, the three 207B pond cells had held process waste. However, in 1977 the sludge from all of the 207B ponds was removed and the ponds were relined. These activities were related to construction of the reverse osmosis facility and the related plant water recycling. Since the 1977 cleanout, the 207B ponds have not contained process waste but have held treated sanitary effluent, treated water from the reverse osmosis facility, backwash (brine) from the reverse osmosis facility, and contaminated ground water pumped back to the Solar Ponds from the ITS.

Pond 207C was constructed to provide additional storage capacity and to enable the transfer and storage of liquids from the other ponds so that they could be taken out of service for repairs.

The routine placement of process waste in the Solar Ponds ceased in 1986. Since 1986, the 207B ponds have received pumped-back ground water from the ITS. After Pond 207B-North reached capacity, this water was transferred to the other 207B ponds. The 207B ponds have slowly reached capacity since 1986. Pond 207C has continued to store and treat process wastes.

Since 1986, activities related to the Solar Ponds have largely focused on Pond 207A. The removal of sludge from Pond 207A began in 1986. This sludge was removed, mixed with portland cement, and solidified to produce pondcrete for disposal offsite. As sludge was removed from Pond 207A, water was removed from the pond by natural evaporation and by forced evaporation using evaporators located in Building 374. Because of these efforts, Pond 207A was essentially empty of materials in the summer of 1988. The last few hundred gallons of water were transferred to the 207B ponds in order to allow inspection of the bottom and relining operations to be initiated. The berms of Pond 207A were relined in 1988, but contaminated ground water was not transferred from the 207B ponds into this

pond until March 1990 when the 207B ponds were reaching capacity. All liquids and sludges were again removed from Pond 207A in late 1992.

### 2.1.9 Waste Characterization

Considerable characterization work on the liquids and sludges in the Solar Ponds was conducted in 1984 through 1986, and an extensive program of sludge and liquids sampling and analysis was performed at the Solar Ponds in the summer of 1991. The general results of this testing indicated that the liquids from Ponds 207A and 207C contained concentrations of nitrate, metals, and radionuclides that were approximately two orders of magnitude higher than those in Ponds 207B-North and Center. Analytical results indicated that Pond 207A was generally more contaminated than Pond 207C, except for plutonium and americium, which were approximately ten times higher in Pond 207C. Plutonium and americium were not detected in Pond 207B-North.

Tables taken from the Phase I RFI/RI Work Plan (EG&G, 1992) which summarize the results of sludge and liquid sampling appear in Appendix B. Concentrations are generally lower in 1991 than in earlier years.

### 2.1.10 Halliburton/NUS Treatability Studies

Studies were conducted on Solar Pond wastes in 1992 by Halliburton/NUS (Halliburton/NUS, 1992a and 1992b) to characterize the waste materials and develop a chemical stabilization and solidification formula that produces a final waste form that passes all regulatory certification requirements and Nevada Test Site acceptance criteria.

The treatability studies were conducted in phases. Phases I and II consisted of an evaluation of waste materials interacting with one another and cement and fly ash combinations, and an evaluation of formula additives to enhance long-term durability of the final waste form. Phases III and IV included experiments to determine an operating envelope in which the formulation produced a final product that achieved all regulatory and acceptance criteria.

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The selected chemical stabilization and solidification binder consisted of Type V portland cement, Type C fly ash, and hydrated lime. Conclusions from these studies suggest that:

- Characterization data are sufficient to establish that pond waste variability is within acceptable ranges;

- Although potential stabilization inhibitors are present in the wastes, successful stabilization using cement, fly ash, and lime can be developed for this matrix;

- Constituents within the ponds are compatible and produce no adverse or abnormal chemical reactions when mixed, allowing waste consolidation;

- The final waste form will be considered a solid waste;

- The final waste form will achieve acceptable strength as measured by unconfined compressive strength; and

- The final waste form will pass Land Disposal Restrictions (LDRs) and toxicity characterization standards.

## 2.2 POND CLEANOUT PROGRAM

Solar Pond cleanout activities have occurred over a long period of time. Some cleanout activities were conducted to allow pond maintenance activities to take place, such as re-lining. From Fall 1976 to Fall 1977, the 207B ponds were cleaned and decommissioned with respect to use for storage of process wastewater. This cleanout activity supported the water recycle program implemented by RFP. During the cleanout process, soils to the south, east, and between individual ponds were removed. Process waste was not re-introduced to the ponds upon completion.

The cleanout of process waste sludge in the 207A pond began in 1986 with the construction of Building 788 and the adjacent clarifier. The clarifier was constructed between Ponds 207A and 207C to mix Solar Pond sludge and portland cement to form pondcrete. This activity, along with transfers of Solar Pond water to Building 374 for evaporation, helped remove both sludges and liquids from the Solar Ponds.

### 2.2.1 Pondcreting

The pond sludge and sediments were transferred to a pug mill where sludge and portland cement were mixed to form pondcrete. The pondcrete flowed over a weir, through a chute, and into boxes for packaging. The portland cement handling system had pneumatic transfer and metering capabilities. The boxes were made of triple-wall fiberboard, were lined with 0.011-inch plastic, and had a capacity of approximately 15 cubic feet. Boxes of immobilized sludge were stored in a prefabricated metal building for curing, labeling, and shipment to the two asphalt pads.

Pondcreting activities through May 1988 have resulted in a total of 16,199 boxes of pondcrete. The solidified pondcrete is stored onsite at two locations. The first location is at the 750 Pad and has a total storage capacity of 14,906 boxes. As of May 1, 1988, 11,798 boxes of pondcrete were stored at the 750 Pad. The second location is east of Building 886 and is designated the 904 Pad, with a capacity of 12,000 boxes. The total storage on May 1, 1988 was 4,401 boxes. The actual number currently may have changed significantly since that time.

Production at the pondcreting facility is, or has been, adversely impacted by:

- Cold weather causing a retarding of pondcrete solidification and causing the liquids in the ponds and de-watering unit to freeze;

- The lack of capacity to store the pondcrete boxes while the contents are solidifying before approval for offsite shipment is given;

- Quality control problems in pondcrete mixture formulation;

- Quality control problems in container receptacles; and

- Periodic equipment failure.

Due to a variety of issues, the pondcrete containers and contents were deemed unsatisfactory for shipment or disposal. Unverified information suggests a range of physical consistency from that of toothpaste to extremely hard and brittle, subject to fracture.

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## 2.2.2 Volume of Sludges and Sediments

As previously discussed, all sludges and sediments have been removed from Pond 207A. The volume of sludge in Pond 207B-North, Center and South, and Pond 207C is estimated to be 705, 705, 720, and 745 cubic yards, respectively, based on dry weight. The sludge volumes are based on visual estimates of a depth of eight inches of sludge in the ponds.

## 2.2.3 Water Management Program

Removal of the pond liquids is currently being performed as part of an Interim Measure/Interim Remedial Action (IM/IRA) which was approved by the agencies and presented for public review. Three half-million gallon surge tanks have been constructed for containing the water collected by the ITS, and two flash evaporators have been installed in Buildings 374 and 910. Pond 207A is the only pond completely empty, and the schedule for cleaning Pond 207C and the 207B series ponds remains uncertain.

## 2.3 PHASE I RFI/RI PROGRAM

The Phase I RFI/RI is focusing on the characterization of sources and soils. The program includes a comprehensive vadose zone investigation consisting of the installation of 16 vadose monitoring wells equipped with suction lysimeters and neutron probe casing tubes for periodic monitoring of unsaturated flow and pore liquid chemistry.

Soil borings will be drilled, and vadose monitoring wells will be installed in Pond 207A, around the perimeters of the other four ponds, and in other areas of OU4. Recent findings of the investigation indicate that channeling of the bedrock surface may provide primary control of the unconfined alluvial ground water flow. Seismic refraction surveys will be performed to establish better resolution of the bedrock surface.

All investigation and remediation activities required by the IAG for OU4 assumed that the ponds would be cleaned out and made available. The Phase I RFI/RI program will be modified to account for only one of the ponds being empty. The original milestone for the submittal of a draft Phase I RFI/RI report has been extended from May 1993 to May 1994.

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# 3.0 REGULATORY SETTING

Presented in this section is a discussion of regulatory matters related to in-place closure of the Solar Ponds. Information is presented on not only existing laws, regulations, and agreements but also certain proposed or draft regulations that have not yet been promulgated. While an attempt has been made to discuss and evaluate all pertinent regulations, detailed regulatory requirements are subject to interpretation and negotiation.

The text includes references to the Code of Federal Regulations (CFR) and the Federal Register (FR) where appropriate. Federal regulatory citations are provided where Colorado regulations are equivalent to federal regulations or where a Colorado agency has enforcement authority for federal programs.

## 3.1 OVERVIEW OF SOLAR POND REGULATORY STATUS

The Solar Ponds are considered in this report to be a single RCRA interim status unit undergoing site characterization and, potentially, remediation activities in response to both RCRA and CERCLA requirements. A RCRA Part A Permit Application in November, 1980 established interim status for the Solar Ponds. The first regulatory document that addressed closure and remediation of the Solar Ponds was the Compliance Agreement signed July 31, 1986 by the U.S. Environmental Protection Agency (EPA), Colorado Department of Health (CDH), and the U.S. Department of Energy (DOE). This Compliance Agreement, and the documents required by it, governed the activities at the Solar Ponds until January 1991 when it was replaced by the Inter-Agency Agreement (IAG) signed by EPA, CDH, and DOE. The IAG creates a unique blending of RCRA and CERCLA requirements. For interim status closure units outside of buildings, the IAG required that the site characterization work be broken up into two phases. Phase I is to characterize soils and sources of contamination, sufficient to determine the risk associated with the source of contamination at each interim status closure unit external to buildings. Following these Phase I characterization activities, an IM/IRA decision document is to be prepared in accordance with Paragraphs 15 and 150 of the IAG. The IM/IRA is to provide the information necessary to recommend an alternative consistent with the CDH closure

regulations, and address cleanup of all hazardous substance source areas with risk levels greater than $10^{-6}$ measured at the source. Phase II site characterization and remediation activities are to address ground water contamination at these interim status closure units outside of buildings.

Closure activities at the Solar Ponds have been ongoing since approximately August 1985, when activities related to sludge removal and treatment began on a nearly full-time basis. Consistent with the desire to close the Solar Ponds, and consistent with the terms of the 1986 Compliance Agreement, a RCRA interim status closure plan for the Solar Ponds was submitted to EPA and CDH in August 1986. A slightly revised RCRA interim status closure plan for the Solar Ponds was submitted to the agencies in November 1986. An interim status closure plan, revised to address written and verbal comments received from CDH on the earlier closure plans, was submitted to the agencies on March 1, 1987. A final interim status closure plan was submitted to the agencies on July 1, 1988. This final closure plan contained revisions in response to written and verbal comments from CDH and EPA regarding the March 1987 closure plan. None of the closure plans were ever approved by the agencies.

The Solar Ponds were also the subject of a 1989 Agreement in Principle (AIP) signed by the Governor of the State of Colorado and by the Secretary of DOE. The AIP required that all sludge be removed from the Solar Ponds, as well as shipping all pondcrete offsite, by October 1991. It has not been possible for RFP to comply with the schedule for sludge removal and pondcrete shipment identified in the AIP.

The first remedial action for the Solar Ponds was a 1992 IM/IRA. This IM/IRA is addressing the design and construction of storage tanks and evaporators to store and treat contaminated ground water collected in the Solar Pond area and is currently ongoing.

## 3.2 RCRA INTERIM STATUS CLOSURE REGULATIONS

RCRA regulations are much more specific and stringent than the CERCLA regulations and will, therefore, govern closure activities at the Solar Ponds. The general requirements for

closure of an interim status unit are identified in the RCRA interim status regulations (40 CFR 265.110 to 265.120). More specifically for interim status surface impoundments, the closure requirements are identified in 40 CFR 265.228. In general, the existing interim status closure regulations require that a unit must be closed in a manner that:

- minimizes the need for further maintenance (40 CFR 265.111(a));

- controls, minimizes or, eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere (40 CFR 265.111(b)); and

- allows completion of closure activities within 180 days after receiving the final volume of hazardous wastes at the hazardous waste management unit or facility, or within 180 days after approval of the closure plan if that is later (40 CFR 265. 113(b)).

Extensions to the 180-day closure period are allowed if it is demonstrated that: the closure activities will, of necessity, take longer than 180 days (40 CFR 265.113(b)(1)(i)); and all steps are taken to prevent threats to human health and the environment from the unclosed but not operating hazardous waste management unit, including compliance with all applicable interim status regulations (40 CFR 265.113(b)(2)).

More specifically for closure of interim status surface impoundments, the regulations require that the closure either meet the requirements for a "clean closure" or the requirements for closure as a disposal unit (also known as a non-clean or "dirty closure"). Clean closure is achieved through removal and decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate. The materials removed or decontaminated must be properly handled and disposed of, including potentially disposing of the materials as a hazardous waste (40 CFR 265.228(a)(1)). Standards used to identify removal of all waste and contaminated materials are typically identified on a case-by-case basis. However, the following classes of soils are adequately clean to allow clean closure:

- soils remaining in place that have no contaminants derived from the closing unit associated with them;

- soils remaining in place that contain "background" levels of contaminants (typically identified in Colorado as the mean background concentration plus or minus two standard deviations);

- soils remaining in place that are demonstrated through a risk assessment to pose a risk of less than 1 in 1,000,000; or,

- soils remaining in place that are demonstrated to meet some other soil standard protective of human health and the environment.

Closure as a disposal unit essentially requires that the surface impoundment area be closed in similar manner as a landfill. Closure as a disposal unit requires that: any free liquids present in the surface impoundments either be removed or solidified (40 CFR 265.228(a)(2)(i)); remaining wastes be stabilized to a bearing capacity sufficient to support final cover for the unit (40 CFR 265.228(a)(2)(ii)); and, the surface impoundment be provided with a final cover (40 CFR 265.228(a)(2)(iii)). In order to meet the requirements identified in 40 CFR 265.228(a)(2)(iii), the final cover must:

- provide long-term minimization of the migration of liquids through the closed impoundment;

- function with minimum maintenance;

- promote drainage and minimize erosion or abrasion of the cover;

- accommodate settling and subsidence so that the cover's integrity is maintained; and

- have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

The activities required to meet the above objectives are to be described in a written closure plan (40 CFR 265.112(a)) that is amended whenever changes are identified that affect the closure plan (40 CFR 265.112(c)). Additionally, if the unit is to be closed as a disposal unit, a post-closure care and monitoring plan is also required (40 CFR 265.110(b)).


## 3.3 LAND DISPOSAL RESTRICTIONS AND MINIMUM TECHNOLOGY REQUIREMENTS

In the case of clean closure of the Solar Ponds, LDRs and minimum technology requirements (MTRs) have no bearing on closure activities other than determining the types of treatment and disposal options that might be required for any waste or materials removed from the Solar Ponds. Similarly, if contaminated materials such as liners or underlying soils

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in and near the Solar Ponds are treated in place or left in place, the LDR and MTR requirements will not necessarily apply to these remedial actions. On the other hand, if liners and contaminated soils are removed for treatment and are then to be replaced into the location from which they were excavated, the LDR requirements will become effective because these actions constitute placement in or on the land, and therefore qualifies as a land disposal action (40 CFR 268.2(c)). Similarly, the MTRs will also become effective due to the creation of a "new" landfill (40 CFR 260.10 and 40 CFR 264.301(c)). These MTRs would require the construction of two or more liners and a leachate collection system above and between the liners in order to protect human health and the environment (40 CFR 264.301(c)). The EPA Regional Administrator can approve an alternate design and operating practices for such a landfill if it can be demonstrated that the alternatives are at least as effective as the liner and leachate collection system in preventing the migration of any hazardous constituent to ground water or surface water (40 CFR 264.301(d)). Currently available site characterization data indicate that LDR requirements are already met by the soils near the Solar Ponds. However, characterization of soils directly under the Solar Ponds liners has not yet occurred.

## 3.4 DEBRIS REGULATIONS

Debris is a solid material that exceeds a 60-millimeter (mm) particle size that is intended for disposal and that is:

- a manufactured object;
- plant or animal matter;
- natural geologic material; or
- a mixture that comprised primarily of debris, by volume (40 CFR 268.2(g)).

The following materials are not considered debris:

- any material for which a specific treatment standard is provided in 40 CFR 268, Subpart D;
- process residuals such as smelter slag and residues from the treatment of waste, wastewater treatment sludges, or air emissions residues; and
- intact containers of hazardous waste that are not ruptured and that retain at least 75 percent of their original volume.

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Hazardous debris is a solid material that contains a hazardous waste as listed in Subpart D of 40 CFR Part 261 or that exhibits a characteristic of hazardous waste as identified in Subpart C of 40 CFR Part 261 (40 CFR 268.2(h)). To meet LDRs hazardous debris must be treated by technologies determined by the type of debris and contaminant under 40 CFR 268.45.

Hazardous debris can be land disposed if the debris is treated by extraction or destruction technologies as described in Table 1 of 40 CFR 268.45. The debris must also meet certification and notification requirements (40 CFR 268.7(5)). This material would not be subject to Subtitle C regulations. However, this is determined on a case-by-case basis review by EPA (57 FR 160 (2)(b)).

Hazardous debris that contains radioactive waste is subject to treatment standards in 40 CFR 268.45 (40 CFR 268.41(d)).

Debris that does not contain hazardous waste or does not exhibit a hazardous waste characteristic would not be subject to Subtitle C Regulation and could be land disposed (57 FR 160(2)(b)).

## 3.5 PROPOSED CAMU AND HYBRID CLOSURE REGULATIONS

Proposed regulations regarding Corrective Action Management Units (CAMUs) were published July 27, 1990, (55 FR 145, p. 30798). A summary of the effects of CAMU regulation on projects was published by EPA on October 16, 1992 under the title, Supplemental Information on Corrective Action Management Units. The basic concept of the CAMU allows broad areas of surface contamination (possibly including more than one solid waste management unit) to be combined into a single waste management unit. These CAMUs would be exempt from LDRs and MTRs under certain conditions to facilitate effective remedial actions.

Two basic CAMU concepts are being considered. The first is defined as an area within a facility designated by the EPA Regional Administrator for the purpose of implementing

Corrective Action Requirements, which is broadly contaminated by hazardous wastes, and which may contain discrete, engineered land-based subunits.

As outlined in the proposal, the following provisions and restrictions would apply:

- It may function only for the management of remedial wastes;

- It must contain contiguous areas of contamination;

- Movement or consolidation of wastes within the unit would not automatically trigger LDRs or MTRs.

- It must be designated by the EPA Regional Administrator;

- Non-land based units are not considered part of the unit;

- Closure and post-closure requirements for the unit would be determined by the authorized agency as part of the remedy and permit modification process. Technical standards would be determined on a case-by-case basis; and

- Hazardous wastes that are placed into a CAMU from outside the unit or waste that was excavated from the CAMU, treated in a separate unit and redeposited, would be subject to RCRA LDRs.

The second concept, the expanded CAMU, broadens the flexibility of the basic rule and includes the following provisions:

- The areal extent of the unit would not necessarily be restricted to contiguous areas of contamination;

- Placement or replacement of hazardous remedial wastes into a CAMU would not trigger LDRs and MTRs;

- More than one CAMU could be used for remedial purposes at the facility;

- Placement of wastes from one CAMU into another would not trigger LDRs or MTRs; and

- Uncontaminated land could be included in the CAMU if necessary.

The feasibility of a cost-effective in-place closure of the Solar Ponds would be greatly enhanced by application of the CAMU concept, and exemption from LDRs and MTRs.

EPA has noted that the two CAMU options are likely to result in a substantial decrease in remedial costs compared to remediations not using the CAMU concept (U.S. EPA, 1992). Finalization of CAMU regulations appears probable.

The Hybrid Closure concept, as published on March 19, 1987 (52 FR 53, p. 8713), introduces a closure approach which combines the strategies of closure by removal and closure as a disposal unit. This hybrid consists of removal of the majority of contaminated materials and would allow covers and post-closure monitoring to be designed for the exposure pathway of concern. This concept has not been finalized, and updates regarding movement of wastes and or treatment have not been identified. Any in-place closure option for the Solar Ponds would clearly be considered a hybrid closure.

## 3.6 CERCLA REQUIREMENTS

CERCLA requirements are much more performance driven and, therefore, have fewer specific technical requirements associated with them when compared to the RCRA regulations. CERCLA clean-up standards applicable to federal facilities are set forth in Section 121 of CERCLA. For sites on the National Priorities List, the requirements are relatively clear. All legally applicable or relevant and appropriate requirements (ARARs) of federal environmental laws, and those requirements contained in state or local environmental laws that are more stringent than federal ARARs, must be applied to remedial actions at federal sites. The ultimate determination of clean-up standards is discretionary and typically involves selection of the most stringent clean-up standard based upon an evaluation of both ARARs and a risk assessment that is completed for the site. Since most of the activities identified under the CERCLA requirements have an equivalent counterpart identified in the RCRA regulations to which specific requirements are attached, further discussion of CERCLA requirements will not be presented in this document. One significant difference between CERCLA requirements and RCRA regulations is that under CERCLA, EPA has the authority to regulate the clean-up of radionuclides. RCRA does not grant this authority to the EPA, nor has Colorado adopted any rulemaking which gives the CDH the authority to regulate radionuclides under the state RCRA regulations.

## 3.7 RADIONUCLIDES

DOE has the authority to regulate radionuclides at RFP and at other DOE weapons facilities. It is DOE that has largely established the definitions of the types of radioactively-contaminated wastes generated at DOE facilities. At RFP the three types of radioactive wastes are, in order of increasing radioactive content, low-level, transuranic, and residue radioactive wastes. Each of these wastes can also be mixed with hazardous waste creating "mixed wastes." Although the distinctions between low-level, transuranic, and residue wastes are clear, there has not yet been any guidance or rulemaking on DOE's part that addresses the issue of how one determines whether a material is a non-radioactive waste or a low-level radioactive waste. To state it another way, no de-minimis level of radioactive content has been established within the DOE complex below which a material is considered a non-radioactive waste. Similarly DOE has not yet established an environmental clean-up standard for radionuclides. At times, however, RFP has attempted to identify its own site-specific de-minimis level of radioactivity for certain materials. However, these de-minimis numbers have never been formalized nor have they been approved by DOE audit teams.

A transuranic waste is a waste that contains greater than 100 nanoCuries per gram of transuranic elements. Transuranic elements are those elements with an atomic number greater than that of uranium. The intent is for the Nevada Test Site to accept low-level radioactive waste (whether mixed waste or not) while the Waste Isolation Pilot Plant would accept transuranic wastes. The level of scrutiny and concern that has been attached to transuranic waste has made it impractical to propose that transuranic wastes be left in place at the Solar Ponds in the past. However, changing public perceptions may create new options for in-place closure.

CDH has set a state standard for plutonium in soil in response to past problems at RFP. This regulation states that soils in uncontrolled areas that exceed 2.0 disintegrations per minute per gram (dpm/g) of plutonium in dry soil or 2.0 disintegrations per minute per square centimeter of soil surface present a sufficient hazard to public health to require the use of special construction techniques to minimize the resuspension of plutonium from the soil. As in criteria that have been published by the Nuclear Regulatory Commission (NRC)

and EPA, this CDH criterion is a concentration below which RFP would be exempted from even considering the issue of radionuclides. The method by which CDH tests for excessive amounts of surficial plutonium contamination is by compositing 25 samples of surficial soils (down to a depth of 1/4-inch) over a 10-acre area and analyzing for plutonium.

EPA first published a draft regulation concerning acceptable levels of transuranic elements in surficial soils in the mid-1970s. These draft regulations were revised and re-published in the mid-1980s and finally published in an informational paper in 1990. The standard that was proposed by EPA in this document was a surficial activity of 0.2 microCuries of transuranic elements per square meter. If this is converted to an equivalent mass-based threshold, transuranic element activities of less than 44.4 dpm/g are considered acceptable. This represents a concentration below which no action needed to be considered. Above this concentration, action should be considered but is _not_ required.

Based on studies of soils in the Solar Pond area to date, none of the soils exceed the EPA informational criterion of 44.4 dpm/g. In fact, few soil samples have been found that exceed the CDH standard of 2 dpm/g plutonium in soil.

## 3.8 NATIONAL ENVIRONMENTAL POLICY ACT

All major federal actions having a significant impact on the environment require National Environmental Policy Act (NEPA) documentation. At the current time RFP has an environmental impact statement (EIS) which covers maintenance and operations activities related to weapons production. As of January 1991 the weapons mission of RFP was canceled, leaving RFP with a mission primarily focused on environmental restoration and decontamination and decommissioning of weapons-related production facilities.

The current intent of RFP is to include environmental activities in a new site-wide EIS currently under preparation. Ongoing Solar Pond sludge clean-out work, however, has been addressed through an environmental assessment and a resulting Finding of No Significant Impact. It is possible, though, that in-place closure of the Solar Ponds will pre-date completion of the new site-wide EIS for environmental activities. If the remedial actions

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involve new operations or construction of new processing facilities, then additional NEPA documentation may be required. This documentation would consist of, at a minimum, an environmental assessment or, possibly, an EIS. The need for NEPA documentation and the type of NEPA documentation to be completed have not been clearly determined at this time.

# 4.0 TECHNOLOGY OPTIONS

This section describes a number of waste treatment and disposal technologies considered to be applicable to Solar Ponds wastes. The technologies are discussed in the context of their ability to achieve the criteria of protectiveness, effectiveness, implementability, cost, and reduction of toxicity, mobility, and volume. Where additional information is needed to better characterize the treatment and disposal options, those data requirements are also identified.

For the most part, the selected methods have a long history of application to hazardous waste sites and a variety of waste types. All have been successfully used at other DOE facilities. All technologies are capable of being designed to meet any risk-based or other performance criteria that may reasonably be applied.

## 4.1 DE-NITRIFICATION

Nitrate and nitrite anions have been identified in the Pond 207C clarifier and all of the Solar Pond waters and sludges. Their presence is undesirable because of their contribution to instability in concrete (Clark et al., 1975) and their toxicity. The instability of concrete caused by calcium nitrate may adversely affect the success of cementing operations. In addition, nitrate is known to cause methemoglobinemia in infants and fetuses (Shuval et al., 1980) and has been limited to 10 mg/l (as N) in drinking water (EPA, 1989). Regulatory efforts to reduce nitrate concentrations in all sources of drinking water (e.g., ground water) are prompted in part by the inability of conventional potable water treatment processes to remove nitrate.

A de-nitrification pretreatment process for the Solar Ponds waste may increase pondcrete stability, decrease waste toxicity, and potentially reduce the volume of any solidified waste. The following sections address two approaches for de-nitrification.

### 4.1.1  Bioremediation

Bioremediation is a treatment technology which employs microorganisms for degradation and destruction of contaminants. Inorganic nitrate and nitrite can be eliminated biologically through the application of de-nitrifying bacteria to convert nitrate and nitrite to nitrogen gas. Biological de-nitrification is an anaerobic process where nitrate acts as the terminal electron acceptor in the oxidation of organic material. In the examples below calcium acetate is the organic substrate which used by the denitrifying bacteria. The in-situ bioremediation of nitrate wastes in open ponds has been successfully demonstrated at Oak Ridge National Laboratories (Napier, 1989). Bioremediation has been successfully demonstrated in batch reactors at Oak Ridge National Laboratories (Napier, 1989) and RFP (Silverstein et al., 1992; Cutter, 1992).

### 4.1.1.1  In-situ Bioremediation

As part of the uranium recycle process at the Oak Ridge Y-12 plant, acidic nitrate wastes are generated. These nitrate wastes, as well as wastes from other processes within the plant, were stored in four unlined waste ponds which were constructed for this process. The ponds had a combined volume of 10 million gallons. The waste consisted primarily of nitrate, heavy metals, and organic compounds. In 1983, an in-situ treatment process for the ponds was developed and the nitrate wastes were biologically decomposed into nitrogen and carbon dioxide. After treatment, the ponds were filled with rocks and covered with an approved multiple-layer cap in 1989.

Bioremediation at the Oak Ridge Y-12 plant was very effective in reducing the total nitrate concentration. Initial concentrations of 8,000 milligrams/liter (mg/l) were reduced to 46 mg/l (as $NO_3^-$) in only 38 days. After de-nitrification an aerator was installed in the ponds, and the total organic carbon (TOC) in the pond was reduced from 510 mg/l to 250 mg/l in a little over 17 days. *Pseudomonas stutzeri* bacteria were used in this process, but activated sludge obtained from any waste treatment plant could have been used. Next, the effluent was pumped through a precipitation and floculation process to remove trace amounts of solids and uranium. This required the pH to be lowered to 2 to remove carbonate ions. Ferric sulfate was then added, and the pH was increased to 10 to induce

co-precipitation of ferric hydroxide and other hydroxides or oxides. The process was found to have a temperature operating range of 10 to 45 degrees Celsius (°C), and a pH operating range of 6.5 to 9.4. In summary the process involved the following key steps:

- neutralization of the ponds;

- settling of the solids;

- de-nitrification;

- bio-oxidation to remove any excess organic compounds;

- flocculation to remove suspended solids;

- filtration and release through a permitted point; and

- return of solids to the ponds.

The situation at the Solar Ponds is very similar to that at Oak Ridge. The Solar Ponds are presently basic and would initially require neutralization with an acidic solution. The sludge and pond water would then be anaerobically mixed. The bio-oxidation step would be used to reduce the TOC concentration and to digest biomass. The other steps in the process may or may not be required depending on the disposition of the waste.

Care must be taken to ensure that the mixing occurs anaerobically, as the process will slow down or cease if oxygen replaces nitrate as the terminal electron acceptor. Although this was not a problem at Oak Ridge it may require a cover at the Solar Ponds. A small contained treatment study in each of the Solar Ponds would be required to study the effects of the contaminants on the de-nitrifying process before committing to this technology.

### 4.1.1.2 Ex-situ Bioremediation

After the closure of the waste ponds in 1989, the Oak Ridge Y-12 plant installed several large 500,000 gallon tanks for use as biological reactors. These large biological reactors used the same process that was used on the ponds. After de-nitrification, the water was passed through a settling tank and a waste water treatment process to remove the solids.

In 1992, two experiments were conducted at RFP to investigate activated sludge de-nitrification process optimization using a synthetic saltcrete brine and three sequencing batch reactors (SBRs). The first experiment involved investigating the rate of supply of carbon and nitrogen substrates (waste throughput). The second set of experiments investigated using a pH control system to optimize the de-nitrification process.

Initial concentrations of 6,000 mg/l were reduced to below detection limit (50 mg/l as $NO_3^-$) in a little over 4 hours. Activated sludge obtained from a local waste treatment plant was used. The process was found to have a temperature operating range of 10 to 45°C and a pH operating range of 7.4 to 9.5. SBRs permit efficient separation and recycling of the biomass. SBRs are also easy to scale up from bench scale to prototype. The final process involved the following key sequence steps:

- fill (1 hr/cycle);
- react (4.5 hr/cycle);
- settle (2 hr/cycle); and
- decant (1 hr/cycle).

Full scale operation at the Solar Ponds would require additional bench testing of the actual pond water sludge slurry. The process would also require scaling up to a prototype process adequate in size to handle the volume of wastes contained in the Solar Ponds and clarifier.

### 4.1.2 Electrochemical Ion Exchange

In the electrochemical ion exchange (EIX) process, waste effluent is pumped through an ion exchange column where the nitrate is removed by ion exchange. Ion exchange has been previously demonstrated to be effective in treating water with nitrate contamination, providing decontamination factors (ratio of influent concentration to effluent concentration) of approximately 100. The primary difficulty with ion exchange treatment has been waste disposal. The nitrate must be removed by regeneration with a brine solution, which ultimately becomes nitrate-containing waste for treatment and disposal.

EIX eliminates the residual disposal requirements. In the EIX unit, the nitrate-selective anion exchange resin bed is "sandwiched" between anion-permeable membranes. Electric

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current is used to continuously remove the nitrate from the resin and migrate the nitrate through the anion-permeable membrane to an electrode where the nitrate is reduced to nitrogen and water. Because the resins are electrically regenerated on-line, the removal/regeneration process is a steady-state process.

This system has been developed through pilot-scale testing and has performed well in several studies, one of which occurred at RFP (Atkins, et al. 1992). Bradtec performed a laboratory demonstration of the EIX process to both recover and destroy the nitrate in a synthetic saltcrete brine. The successful de-nitrification of the synthetic brine required the following additional steps:

- filtration of the brine before entering the EIX process;
- pH control to prevent precipitation in the resin chamber; and
- dilution of the nitrate solution to avoid back-diffusion of nitrate through the membrane.

Additional data are required to determine the applicability of this technology to Solar Ponds wastes. These data requirements include:

- bench- and pilot-scale testing data obtained from Solar Pond sludge/slurries represent the waste's chemical and physical characteristics;
- verification that resin and membrane fouling is not a problem;
- verification that undesirable redox products are not created; and
- an analysis of the ability to scale up the process to a size adequate to handle the volume of wastes contained in the Solar Pond clarifier.

### 4.1.3  De-nitrification Summary

De-nitrification as a pretreatment process should help improve the protectiveness and effectiveness of any anticipated waste treatment system. It should also enhance the reduction of toxicity and mobility of contaminants in the treated waste. With respect to the volume of treated waste, de-nitrification may offer some advantages if concreting is used to solidify the waste. If it is not followed by concreting, de-nitrification is not likely to alter the final volume of treated waste. De-nitrification is expected to be a readily implementable technology at the Solar Ponds with a moderate associated cost.

## 4.2    DECANTING/DE-WATERING

The handling and disposal of sludges and slurries represent a major cost component of any Solar Ponds remedial alternative. Sludge and slurry volume reduction through decanting or de-watering can be instrumental in reducing this cost (WPCF, 1985).

### 4.2.1    Decanting

Decanting is the process of drawing off the supernatant (overlying) fluid without disturbing the sediment or the lower liquid layers. The water above the sludges will be decanted and treated separately unless it is needed for the selected sludge treatment process. This water could be treated at RFP using existing treatment facilities located in Building 374.

Decanters used for supernatant removal can be either floating or manually adjustable. Several floating decanter designs exist and have been used successfully. Normally, they include an exterior baffle to exclude scum from the supernatant and an internal weir over which relatively clear supernatant can flow. Fixed decanters include telescoping valves and weir gates. Decanting is often done immediately before removing the sludge.

If the supernatant fluid (the pond wastewater) contains suspended solid particles with a higher specific gravity than the liquid, a settling process may be needed before the decanting process is begun. The pond itself can act as the settling basin if the pond can be kept in a relatively quiescent state to allow gravity to naturally settle out the particles, otherwise a clarifier will need to be used (WEF, 1992).

### 4.2.2    De-watering

De-watering of the sludges is desirable to reduce the volume of sludge to be treated and to produce a treated product that will be dry enough for bulk handling and possible placement in an existing pond or cell.

The extent of de-watering and the required de-watering technology will depend on the sludge treatment process selected. The treatability studies for Pond 207A and the 207B

ponds (Halliburton/NUS, 1992a and 1992b) reported results from several vendors using different technologies as follows:

| Technology | % Solids after De-watering |
|---|---|
| Drum Filter Screen | 20 |
| Belt Filter Phase | 30 - 35 |
| Plate and Frame | 50 - 60 |

Tests were performed with several polymers to determine their ability to produce a flocculated sludge more readily de-watered by a drum filter. The testing of polymers determined that a high-molecular-weight cationic polyelectrolyte produced a floc which is most compatible with a drum filter screen. Some experiments were also conducted on the pond sludge to determine the ability of a clarifier or thickener to provide a more concentrated sludge prior to de-watering.

De-watering pond sludges is a step which will likely precede their further treatment. It is effective in reducing the volume to be treated, but is not very effective by itself in protecting human health and the environment or in reducing toxicity or mobility of contaminants.

De-watering may not be useful or required for all waste treatment technologies. Treatability studies by Halliburton/NUS for Pond 207C and the clarifier indicated that for pondcreting water should be added to the contents of the pond and clarifier materials to dissolve the salts and to keep the total solids in an acceptable range.

Costs for drying sludges to the levels required for various treatment technologies need to be included in the total treatment costs. Further testing of the sludges may be required to determine the most effective method for de-watering.

## 4.3 SLUDGE WASHING

The high volume of Solar Ponds sludge and existing pondcrete contributes significantly to the cost and the difficulty of treatment and disposal. Sludge washing is a technology with

the potential to concentrate contaminants in a residual sludge as a pretreatment step, facilitating the application of other remediation processes. In reducing the volume of sludge that must be treated, sludge washing can reduce the overall cost.

Sludge washing, as discussed in this report, is an ex-situ, water-based process that employs chemical and physical extraction and separation processes to remove organic, inorganic, and radioactive contaminants from sludge. It is usually employed as a pretreatment process to reduce the volume of feedstock for other remediation or stabilization processes. The contaminated sludge is excavated and staged, pretreated to remove oversized material, and washed with water to separate and segregate the contaminants. The process recovers a clean sludge fraction and concentrates the contaminants in another sludge portion.

Surficial contaminants are removed through abrasive scouring and scrubbing action in a step using a wash water which is sometimes augmented by a surfactant or other agent. The sludge is then separated from the spent washing fluid, which carries with it the contaminants. The recovered sludges consist of a clean coarse fraction (>230 mesh). The contaminated fines typically carry the bulk of the chemical contaminants and generally require further treatment using another remediation process, such as stabilization. Removal efficiencies may, in some circumstances, be enhanced by the addition of heat, surfactants, acids, or chelating agents.

Washing performance is highly sensitive to sludge grain size distribution. It is most appropriate for noncomplex sludges that contain at least 50 percent sand and gravel. It is relatively ineffective for sludges that are rich in clay- and silt-sized particles or that have a high concentration of mineralized metals. Further, sludges with a relatively high cation exchange capacity or a high humic content tend to bind contaminants more tightly, limiting the ability of the sludge washing process to effectively separate the contaminants from the sludge.

The sludge matrix may present other limitations to the effectiveness of sludge washing. Complex mixtures of contaminants make it difficult to formulate a single suitable washing

fluid and may require sequential washing steps with different additives. Further, frequent changes in the contaminants and their concentrations in the feed sludge can disrupt the process, requiring modification of the wash fluid formulation and the operating parameters.

Another potential problem is that chelating agents, surfactants, and other additives may be trapped in the contaminated sludge and treated sludge residuals potentially increasing the difficulty of residuals management.

An ex-situ soil washing demonstration project has been carried out under the Superfund Innovative Technology Evaluation (SITE) program. Using a pilot-scale unit with a treatment capacity of 500 pounds per hour, the demonstration showed that for soils containing 25 percent or less of fines, the process can segregate a low-volume, high-concentration fraction of the soil from the remaining lower-concentration material. While the demonstration project was applied to a site contaminated with organic compounds (achieving 87 percent removal efficiencies), the basic technology could be used for metal contamination as well.

As a pretreatment technology, sludge washing does not affect the protectiveness, implementability, or reduction in toxicity and mobility of the overall waste treatment and disposal process. However, given the large volumes of material to be treated and disposed at the Solar Ponds, the possibility of concentrating the contaminants in a low-volume fraction of the waste makes sludge washing a potentially promising technology. However, the lack of detailed information concerning the sludge characteristics and chemistry creates considerable uncertainty.

Sludge characterization is the first and most important step in determining whether the Solar Ponds sludges may be effectively washed. Removal efficiencies are highly dependent on the specific blend of physical and chemical characteristics of the sludges and the contaminants and the spatial distribution of contaminants throughout the ponds. Table 4-1 summarizes key sludge parameters that should be measured in order to develop an accurate profile of

**Table 4-1**
**Sludge Characterization Requirements**

| Parameter | Purpose and Comment |
|---|---|
| **Key Physical Parameters** | |
| Particle size and distribution | |
| >2 mm | Oversize pretreatment requirements. |
| 0.25 - 2 mm | Effective soil washing. |
| 0.063 - 0.25 mm | Limited soil washing. |
| <0.063 mm | Clay and silt fraction - difficult soil washing. |
| Cation Exchange Capacity | A measure of sludge's ability to attract and bind pollutants in exchange for naturally occurring ions or elements. |
| **Other Physical Parameters** | |
| Type, physical form, handling properties | Affects pretreatment and transfer requirements. |
| Moisture content | Affects pretreatment and transfer requirements. |
| **Key Chemical Parameters** | |
| Organic compounds | Determine contaminants and assess separation and washing efficiency, hydrophobic interaction, washing fluid compatibility, changes in washing fluid with changes in contaminants. May require preblending for consistent feed. Use the jar test protocol to determine contaminant partitioning. |
| Concentration | |
| Volatility | |
| Partition coefficient | |
| Metals | Concentration and species of constituents (specific jar test) will determine washing fluid compatibility, mobility, and effectiveness. |
| Humic acid | Organic content will affect adsorption characteristics of contaminants on sludges. |
| **Other Chemical Parameters** | |
| pH, buffering capacity | May affect pretreatment requirements, compatibility with equipment materials of construction wash fluid compatibility. |

the feedstock sludge and to guide sampling efforts in collecting representative sludges for further characterization and for bench- and pilot-scale testing.

Bench- and pilot-scale tests should be conducted on representative contaminated sludge samples to determine whether sludge washing can be used to effectively remove the contaminants and to determine the requirements for sludge feedstock preparation. In addition, these tests provide the bases for gauging the performance capabilities of commercially available systems at the Solar Ponds. However, a final assessment of waste volumes relative to available containment capacity may show that the need for volume reduction through sludge washing does not exist.

## 4.4    SOLIDIFICATION/STABILIZATION

Solidification/stabilization technology, also known as immobilization and fixation, is the process of containing a waste to prevent or minimize the release of its contaminants into the environment. In the narrow sense, solidification changes the physical properties of the soil or waste matrix, for example, by eliminating free liquids. Stabilization changes the physical or chemical properties of the contaminants, for example, by converting metal salts to their insoluble hydroxide forms. The goal of solidification/stabilization is to produce a product with the following characteristics: (1) low leachability, (2) high thermal conductivity (increased heat resistance), (3) high chemical stability over time, (4) high resistance to breakdown by radiation, (5) high mechanical ruggedness, (6) low corrosiveness, (7) low volume, and (8) low cost to produce.

This section describes in-situ and ex-situ solidification/stabilization processes using both generic and proprietary binders. The terms solidification and stabilization are generally used together because the process additives employed usually perform both functions. For simplicity in the following discussion, the term solidification/stabilization is referred to as solidification.

While solidification has historically addressed inorganic contamination, the technology can be applied to media contaminated with both organic compounds as well. In large part, the

inclusion of proprietary binders and additives is intended to incorporate organic contaminants into the sludge/binder matrix or at least prevent the organic compounds from interfering with the solidification reactions.

### 4.4.1 In-situ Solidification

The following sections address the in-situ application of solidification technologies.

### 4.4.1.1 Cement-Based Solidification

The most widely used solidification agent for hazardous wastes is currently portland cement. It is available as a uniform product in several types, including two with moderate to high sulfate resistance. Portland cement may be used alone as the binding agent or formulated with flyash, lime, soluble silicates, clay, and other materials to enhance processing or improve the properties of the final product (Weitzman et al, 1988; Adaska et al, 1991). It is available in bag or bulk quantities and has a long-term successful performance record for use in the solidification of radioactive wastes as well as other inorganic and organic contaminants.

Cement-based solidification ordinarily includes the addition of several non-proprietary, inorganic binders which are combined with portland cement to eliminate certain interactions between the contaminants and a pure cement binder. Some contaminants can interfere with cement hydration or solidification by disrupting the matrix or retarding the setting time. In general, interference problems are more commonly caused by organic compounds than by inorganic compounds. Some common additives for cement-based binders include the following:

- Pozzolans. Insoluble silicates in the form of fly ash, blast furnacee slag, and cement kiln dust react with the calcium hydroxide released by cement hydration to form additional cementatious compounds. Pozzolanic additives generally improve the strength and reduce the porosity of the final product if they are not consumed in competing reactions with the contaminants. Pozzolans can be added to adsorb metals, organic compounds, and excess water.

- Soluble silicates. Liquid forms of sodium and potassium silicates react with the calcium hydroxide released by cement hydration. Soluble silicates form a gel structure that prevents solids from settling out of aqueous wastes before

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the cement sets and hardens. They also encapsulate contaminants that adsorb to cement particle surfaces. The resulting solid may be weaker than portland cement alone.

- Lime. Calcium oxide or calcium hydroxide (hydrated lime) accelerates cement hydration by providing additional calcium hydroxide for the hydration reactions. It is also added to prevent destruction of the cement structure by acidic contaminants.

- Clay. Selected clays such as bentonite absorb free liquids and bind specific anions and cations.

The solidification process starts with the mixing of contaminated sludge portland cement. Water is used in the hydration reactions that bond the cement-sludge-contaminant matrix together. Calcium hydroxide, cement gel, and other compounds form during the hydration process, and bind the sludge and contaminants into the crystalline lattice of the cement matrix. The final product varies from a granular, soil-like material to a cohesive solid, depending on the amount of binder added and the contaminants present in the sludge. As hydration proceeds and the crystallinity of the matrix increases, the porosity and internal surface area decreases. The final product is much less permeable than the contaminated sludge, and the contaminants are physically incorporated and sometimes chemically bonded to the cement matrix. The overall effect is to inhibit the leaching of contaminants from the solidified mass.

Solidification requires equipment for chemical storage, materials handling, materials mixing, and materials control. Dry binder ingredients, such as portland cement, fly ash, and lime, are usually delivered in bulk transport trailers and stored in elevated metal storage silos. Liquid ingredients, such as hydrated lime, and soluble silicates are delivered in both bulk and drummed shipments and are stored in tanks or buildings. Storage tanks and buildings may require protection from extreme heat or cold for year-round operations.

The determination of binder ratios and additive levels is site- and soil-specific. The sludge-to-binder ratio is controlled on a weight or volume basis using weigh batchers or screw feeders available from the concrete batch plant industry.

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Solidification requires the handling and mixing of fine-grained soils and finely-divided binder ingredients. As such, control of volatile organic emissions and fugitive dust generation is necessary during the loading, blending, and discharge operations.

Because of the interferences provided by the presence of fine sludge particles and the contaminants themselves, the setting time of the cemented soil is prolonged. This slow set allows time for the transport and placement of the mixture either in the original pond or in another pond.

In-situ solidification can be accomplished using conventional mixing, excavation, or drilling equipment. If the contaminants are less than 2 feet deep, conventional earth-moving or land-farming equipment can be used for the mixing step. Mixing is unconfined, however, and tends to generate fugitive dust emissions.

Because of the difficulty of monitoring the binder-to-soil ratio in the in-situ approach, binder consumption tends to be higher than direct treatment. Some of the increase comes from the overlapping pattern of binder application, but most is due to the necessity of erring on the high side of the target formulation.

In-situ solidification results in a volume expansion of the treated sludge. Recontouring of the expanded sludge, or consolidation into a designated pond may be required.

Other than the fugitive dust emissions associated with bulk solids transfer, in-situ solidification does not produce any sidestreams. The process involves the injection of a cement slurry into the sludge, so dusting is not likely at the mixing head. Volatile organics may be released from the sludge as mixing proceeds, so the mixing equipment can be provided with a vapor collection hood if volatiles are anticipated.

Portland cement has been used very successfully in the solidification of metals contaminants, which are typically converted to their hydroxides. Hydroxides are typically less soluble than other ionic species of most metals. The effectiveness of solidification depends upon the

level of contamination and the oxidation state of the metal. For example, mercury can be successfully stabilized only at low concentrations. For lead, the pH of a pure cement binder is higher than optimum for minimum hydroxide solubility. An insoluble silicate, such as flyash, can be added to the cement binder to lower the mix pH.

Certain organic waste constituents can interfere with the cement hydration reactions. Chlorinated hydrocarbons adsorb on cement surfaces, retarding hydration and interfering with cement matrix formation. Portland cement has been successfully used to solidify low levels of organic contaminants, including PCBs, oils, and oily sludges, but high levels of organic contaminants require additional binder ingredients. The solidification studies by Halliburton/NUS indicate that the organics present in the Solar Ponds do not interfere with the binding processes enough to make solidification unfeasible.

Processed sludge must be protected from the effects of weathering. Exposure of the matrix to the elements, particularly freeze-thaw cycles, may produce an increase in the leachability of the immobilized constituents. In-situ solidification will require a soil cover layer for freeze-thaw protection as well as for successful revegetation.

Solidification does not destroy organic or inorganic contaminants, but it does reduce their mobility by chemical reaction or physical encapsulation. The immobilization efficiency of the process is measured by comparing the leachability of the contaminants before and after solidification through Toxicity Characteristic Leaching Potential (TCLP) testing.

### 4.4.1.2  Proprietary Binder Solidification

Many vendors offer solidification services that employ proprietary additives in the binder formulation. Typically, the basic binder is still portland cement (Hazcon) or portland cement and fly ash (Soliditech). Some vendors avoid portland cement, but use alumino-silicates (Silicate Technology Corp.) or calcium silicates (Chemfix) in conjunction with other patented additives. In most cases, the proprietary ingredients are intended to improve the stabilization of organic contaminants and reduce the effects of organic and inorganic contaminants on the cement reaction. The literature references a number of proprietary

binders used in the remediation of soils contaminated with chlorinated organic compounds and heavy metals. The metals are generally immobilized, but the success with chlorinated organic compounds has been mixed.

Most vendors offer complete solidification support including treatability studies, materials handling and mixing equipment, operating labor or labor training, and analytical support. Chemfix builds and leases transportable equipment for use with their proprietary solidification additives, Chemset I-20 and Chemset I-220. On the other hand, HAZCON uses conventional transportable cement mixing equipment to add their proprietary additive, Chloranan. Aside from additional storage tanks or silos for the proprietary additive(s), the equipment is the same as that already described under cement-based solidification.

The performance of additives is highly sludge and contaminant specific and cannot be extrapolated from other demonstrations to Solar Ponds applications.

Treatability studies are not yet available for proprietary solidification of Solar Ponds sludge. A survey of solidification vendors should be conducted to determine if any proprietary processes look more promising than the results already obtained with cement binders.

### 4.4.1.3  Deep In-Situ Solidification

Where in-situ solidification is required at greater depths or where minimum emissions from waste components and solidification reagents are required, a device derived from drilling technology can be used. The method incorporates an integrated system of components consisting of:

- Very high-torque, earth drilling equipment (forces to 300,000 foot pounds);
- A hollow stem kelly bar with integral gas/fluid delivery system;
- A system of soil boring/mixing tools that, mounted on the "kelly bar", provide the drilling and mixing action;
- A soil shroud containment/mixing system;
- A computerized monitoring system for control and documentation of treatment; and
- Reagent storage and grout mixing systems.

The tool attached to the end of the kelly bar, and rotated by it, augers into the soil, sludge or other contaminated material, boring to depths of more than 100 feet if required. As the tool bores, it injects a fluid such as a solidification grout into the material, and at the same time mixes the grout thoroughly with the contaminated material. The combined rotary and vertical movements of the tool can be varied in rate and repeated to assure proper missing of the reagents with the waste. Tool forms 4 feet to 12 feet in diameter can be used depending on the size of the project and the depth and nature of the material to be treated. Different tool configurations are used, depending on the soil or waste characteristics. The equipment can be used on most terrains, on sludge ponds, and even under water. Where emission controls are required, the kelly bar passes through a sealed bearing in the top of a hemispherical steel shroud that covers the work area and is sealed around its circumference in the top layer of the material to be treated. Negative pressure is maintained inside the shroud by an air handling system that includes high-efficiency particulate filters, activated carbon, and/or other air treatment sub-systems. This combination of shroud and air handling system effectively eliminates gaseous or particulate emissions.

This process and equipment has been used for 30 years for the construction of ground water barrier walls, foundations for building and other structures, and for general soil stabilization. Most recently, its use was demonstrated for treatment and stabilization of organic contaminated soils at the Portsmouth, Ohio Gaseous Diffusion Plant, Site X231B. The solidification system used for this project was cement/flyash/activated carbon, but most cements and additives can be applied with the equipment.

### 4.4.2 Ex-situ Solidification

The basic process of solidification of Solar Pond sludges after removal from the ponds is the same as the in-situ solidification described above. The ratio of binder to waste can be controlled better than is possible in in-situ solidification, and better uniformity of mixing is usually realized.

The sludge would be removed and transported to the solidification equipment at a central location. Depending on the type of mixing equipment used, the contaminated feed stream could require coarse screening as a pretreatment step. If the sludge and binder are mixed with a pugmill, oversize material could be "entombed" in the processed material as it leaves the mixer. Metering and thorough mixing of the ingredients are essential for achieving consistent solid properties, but any mechanical equipment that uniformly mixes the soil and additives is satisfactory. In general, a pug mill is the most common choice for sludge and binder mixing.

Solidified sludges could be backfilled in the original pond as a bulk material or as a pumpable material. A soil/clay cover would be placed over the material after it has been allowed to cure. For sludges with high levels of inorganic compounds, a liner could be placed in the excavation before backfilling to provide an added degree of engineering control for containment.

### 4.4.3 Other Solidification Processes

There are other solidification/stabilization processes that have been used or are being developed. A polyethylene process for the improved encapsulation of radioactive, hazardous, and mixed wastes has been developed at Brookhaven National Laboratory. Difficulties with cement stabilization of nitrate wastes are attributed to chemical interactions between the waste and binder that interfere with proper cement hydration. Encapsulation of nitrate salts and other mixed wastes in polyethylene does not rely on a chemical reaction for solidification and, thus, is not subject to the type of failure mechanisms experienced by cement systems. Stability under anticipated storage and disposal conditions and compliance with applicable hazardous waste regulations were demonstrated through a series of laboratory-scale waste form performance tests. A scale-up feasibility test was successfully conducted, demonstrating the ability to process nitrate salts at production rates up to 450 kilograms/hour (kg/hr) and the close agreement between bench- and full-scale process parameters. Cored samples from the resulting pilot-scale (114-liter) waste form were used to verify homogeneity and to provide additional specimens for confirmatory performance

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testing. Full-scale demonstration of this process using actual or surrogate waste is currently planned.

If more conventional solidification processes do not produce a final product that meets all the acceptance criteria, the polyethylene encapsulation solution process may warrant further examination as a possible option.

### 4.4.4 Vitrification

Vitrification technology involves the fusion of solid hazardous materials in a molten, vitreous mass which will result in a glass-like product upon cooling. The residual product is usually a solid (super-cooled liquid) containing an amorphous mixture of oxides (primarily silica and alumina) with little or no crystallization. Vitrification involves the destruction (by pyrolytic decomposition and/or oxidation), removal, and/or permanent immobilization (encapsulation) of hazardous contaminants and can be considered both a thermal destruction and immobilization process. The residual product can be cast into containers, formed into multi-thousand pound monoliths, or produced in a granular form. Furthermore, the product usually displays excellent structural, weathering, and biotoxicity characteristics, making it suitable for long-term environmental exposure. Both in-situ and ex-situ processes are discussed below.

### 4.4.4.1 In-situ Vitrification

In-situ vitrification (ISV) is the process of decomposing organic contaminants and melting wastes, soils, or sludges in place. This is accomplished by electrically melting soil at temperatures between 2,900 and 3,600 degrees Fahrenheit (°F). Organic vapors and airborne pyrolized by-products of all organic contaminants and some inorganic contaminants are collected at the surface under a hood and drawn off into a gas treatment system. Electricity is typically supplied by a utility distribution system at transmission voltages of 12,500 or 13,800 volts. The resulting product is a monolithic mass with a microcrystalline structure similar to that of naturally occurring obsidian.

ISV of soils is most effective on fairly homogeneous, high-silica, low-moisture soils that are free of naturally-occurring organic or man-made buried debris. In this process, four electrodes are inserted into the soil to the desired depth, and a carbon/glass frit is placed between the electrodes to act as a starter path for the initial melt to form. As the melt grows downward and outward, it incorporates nonvolatile elements and decomposes organic components by pyrolysis. The pyrolized by-products migrate to the surface of the vitrified zone where they combust in the presence of oxygen. Inorganic materials are dissolved or are encapsulated by the vitrified mass. Convective currents within the melt mix the materials that are present in the soil. When the electric current ceases, the molten volume cools and solidifies.

ISV will result in a volume reduction of 20 to 40 percent, depending on the void volume of the material. This process should not be implemented if individual void volumes exist in excess of 150 cubic feet (including void spaces left by organic matter), buried metals in excess of 5 percent of the melt weight are present, continuous metal occupies 90 percent of the distance between two electrodes, rubble is present in excess of 10 percent by weight, or there is not enough silica contained in the treatment volume to form the desired residual material. During the vitrification process, stack gas monitoring must be conducted to evaluate the effectiveness of the off-gas collection and treatment system.

The process will work with fully saturated soils; however, the water in the soil must be evaporated before the soil will begin to melt. Soils with permeabilities greater than $10^{-4}$ centimeters/second (cm/sec) are difficult to vitrify in the presence of flowing ground water and require some type of ground water diversion or site containment. The effective depth of treatment may extend to no more than 30 feet.

The normal processing rate for a large-scale ISV system is approximately 4-6 tons/hour, with a melt advance rate of 1-2 inches/hour. This processing rate could be increased by use of an additional hood to eliminate downtime between setups or by running several units simultaneously. This process is now commercially available.

If treatability studies demonstrate the effectiveness of this technology at the Solar Ponds, one benefit could be the simultaneous immobilization of the sludge, liner, and sub-soils. In addition, this may be an excellent method of dealing with the existing pondcrete. The cost of treatability testing is typically quite high.

### 4.4.4.2 Ex-situ Vitrification

Ex-situ vitrification (ESV) technologies include electric furnace/melter, plasma centrifugal reactor, and slagging kiln/incinerator (U.S.EPA, 1989).

Electric furnace/melter vitrification units use a ceramic-lined, steel-shelled melter to contain the molten glass and waste material to be melted. These units are very similar to electric furnaces that are used to manufacture glass products. Waste material and glass batch chemicals are fed directly onto the surface of a molten glass bath. The waste is melted as heat is transferred from the molten glass surface to the waste. Volatile organics and inorganic compounds undergo pyrolytic decomposition and/or oxidation. The off gases are then further treated to ensure safe air emissions.

Plasma centrifugal reactor units are fed prepared waste material into a rotating reactor well in which a transferred-arc plasma torch melts the material. The melted material then enters a slag chamber where it is collected in a container. Released volatile compounds are passed to a secondary combustion chamber and oxidized. The off gases are then further treated. The containerized slag must eventually be disposed according to proper procedures.

Slagging kiln/incinerator units are able to process whole drums and mixed waste with little or no pretreatment. Such units are typically very large and are usually offsite. Vitrified product may be cast into containers or granulated.

### 4.4.4.3 Vitrification Summary

Both ISV and ESV result in a high level of protection of human health and the environment and a high degree of reduction in toxicity and volume. Cost, however, is high, and there are questions regarding its implementability at the Solar Ponds.

Because many site-specific variables affect the disposition of specific contaminants in the vitrified product, the implementability of ESV or ISV at the Solar Ponds is uncertain. The primary variables include: physical and chemical properties of the contaminants, melt chemistry, melt temperature, contaminant dwell time in the treatment zone, adjacent soil properties, soil moisture content, and extent of over-melting (soil melted beyond the limit of contamination). Heterogeneous, medium-silica, high-moisture soils may preclude the use of this technology. Finally, complete treatment of all the harmful off gases must be verified.

## 4.5 BARRIERS

Effective in-place closure of the solar ponds may require the inclusion of a vertical barrier to help control the flow of ground water through the solar ponds area. Vertical barriers can be used to provide containment all around a site or they can be placed upgradient of a site and used to divert ground water around a site. The latter option would be the most likely option for use at the Solar Ponds.

### 4.5.1 Types of Barriers

A variety of barrier types could be used at the Solar Ponds, each of which is briefly described below.

#### 4.5.1.1 Slurry Walls

Slurry walls are constructed in vertical trenches that are excavated under a slurry. The slurry, usually a mixture of bentonite and water, acts essentially as a soil porosity sealant. It stabilizes the trench to prevent collapse and, at the same time, forms a low-permeability filter cake on the trench walls that prevent water loss. In some cases, soil or cement is added to the bentonite slurry to form a soil/bentonite or cement/bentonite slurry wall. Slurry walls are typically used when they can be keyed into a confining clay layer or bedrock. They are economical up to moderate depths (40 to 70 feet maximum) and have a low permeability. Slurry walls have been commonly used at hazardous waste and nonhazardous waste sites. There is some concern regarding the permeability of slurry walls to certain organics.

### 4.5.1.2 Grout Curtains

Grout curtains are subsurface barriers created in unconsolidated materials by pressure injection of grout materials. Various methods of forming a grout curtain are available, including borehole injection and vibratory beam injection. The method suitable for a particular site depends on several factors such as depth and geological materials encountered. Spacing of injection points and placement methods directly affect barrier integrity. Grout barriers are much more difficult to install than slurry walls and are generally incapable of attaining truly low permeabilities in unconsolidated materials.

### 4.5.1.3 Sheet Piling

Sheet piles are typically made of precast concrete, steel, or plastics. Concrete is used primarily where great strength is required, but steel is the most effective medium in terms of ground water cutoff. However, because of unpredictable wall integrity between interlocking joints, steel sheet piling is seldom used, except for temporary de-watering during construction (where it is extensively used) or as erosion protection. Sheet piles have been augmented with grout to enhance ground water cutoff. However, sheet piles can be bent or diverted during insertion by boulders, leading to an incomplete barrier.

### 4.5.1.4 Pneumatic Seals

Pneumatic subsurface containment is an emerging technology in which a positive-pressure air seal is established to prevent the migration of contaminants across a designated point. The process creates a pressure gradient to prevent penetration of leachate. This process has had only limited success and is still in the developmental stage.

### 4.5.1.5 Synthetic Membrane Cutoff Walls

Synthetic membranes can be used to form a cutoff wall to divert or contain ground water. Compatibility testing of the liners with chemical waste must be performed to determine durability. To place a synthetic membrane liner as a vertical barrier, a trench is dug from the surface to an impervious soil layer, and a drain is placed on the bottom of the trench to remove excess water. The synthetic membrane is suspended vertically in the trench, and the trench is backfilled with sand and other suitable material. To be effective, the liner

must be keyed into the underlying impervious barrier. During construction, the trench must remain open to facilitate placement of the liner. Extra precautions must be taken in loose, unconsolidated materials to ensure proper placement of the barrier.

### 4.5.1.6 Compacted Soil Walls

Compacted soil walls are often constructed by placing compacted soils in lifts within an open trench and are an alternative to slurry walls under certain geologic conditions. Compacting soil by dropping heavy weights from heights also provides a compacted soil wall. Compacting the soil wall by dropping weights requires predictions of energy and impact spacing requirements, careful control of site operations, and extensive geotechnical testing to verify effectiveness.

### 4.5.1.7 Ground Freezing

This process option uses conventional technology to circulate a low-temperature brine that freezes water around the circulation pipes. With a series of closely spaced pipes, this circulation creates a frozen barrier. The required spacing depends on water chemistry, soil types, and hydraulic conductivities. Freezing is commonly used as a temporary measure to stop the flow of water during underground construction.

### 4.5.1.8 Extraction/Injection Wells

Movement of ground water can be controlled or prevented by use of a specially designed hydraulic barrier system. Excavation/injection wells have a moderate to high operational flexibility, which allows the system to meet increased or decreased pumping demands. If the location and pumping rate of each extraction and/or injection point is based on modeling and pilot testing, the desired hydraulic gradients can be established in predetermined patterns. These gradients can be so arranged to prevent or encourage water movement in a particular direction. This affords opportunities for isolation, de-watering, flushing, or other in-situ treatment of soils in selected areas without excavation. Extraction/injection wells have been used at many sites to prevent migration of contaminants in ground water flow.

### 4.5.1.9 De-water/Recharge Drains

De-watering/recharge drains also can be constructed to prevent or encourage ground water flow. Drains include any type of buried conduit used to convey and collect aqueous discharges by gravity flow. Drains are often constructed by placing tile or perforated pipe in a trench, surrounding it with gravel, and backfilling the trench with soil or clay. The drains function as a continuous extraction or injection line. Drains have been used to de-water a broad variety of sites.

### 4.5.2 Required Conditions

Geologic conditions must be defined sufficiently to determine whether a vertical barrier will work for its intended purpose and evaluate which type of barrier is most appropriate for the site. Cobbles and boulders in the alluvial material above the bedrock at the site raise serious questions about the feasibility of grout curtains and sheet pilings. The thin, saturated zone of alluvial material above the bedrock would be difficult to control with extraction/injection walls. These considerations, along with the high degree of reliability that would be desired for a vertical barrier, suggest that a slurry wall or ground freezing type barrier would be the most likely barrier for the Solar Ponds.

### 4.5.3 Advantage/Disadvantages

A vertical barrier would serve to divert ground water around the site. This would reduce concerns with respect to leaching of any deeper contaminants and subsequent potential migration of these contaminants by ground water transport. Diversion of ground water would also create a thicker unsaturated or vadose zone in which vadose zone monitoring could be performed.

The importance of a vertical barrier will be dependent on the geologic characterization, the nature and extent of contaminants, and the selected remediation technologies.

## 4.6    LINER SYSTEM

Some type of liner may be required for closure of the Solar Ponds. Liners are often an important element for in-place closure of wastes because they are a physical barrier which interrupts exposure pathways.

The existing Solar Ponds have liners, but the effectiveness of those liners must be carefully evaluated if they are to be relied upon. The type of liner required will be a function of the type of treatment performed on the sludges and the resultant characteristics of the final product. Ideally, the treatment technologies selected for the sludge and/or pondcrete will result in delisting. This may relax requirements for additional liners with greater emphasis placed on the cap and monitoring system.

If the treated sludge is delisted and does not have characteristics of concern for the protection of human health and environment, it could be placed in the existing ponds and covered as required to reduce infiltration from the surface. If the treated sludge is delisted, but still has characteristics that would be of a concern with respect to protection of human health and the environment, a liner system following the guidelines for a solid waste landfill could be constructed. However, even if the processed sludges are delisted, regulatory considerations may require a liner system designed to meet the requirements for a hazardous waste, or RCRA, landfill cell.

Since the hazardous waste liner requirements are the most stringent, this would represent the worst-case scenario from a cost perspective. The components of a hazardous waste liner system typically include the following major components from the top down:

- A geotextile filter to separate processed sludge from the rest of the liner system;

- A leachate collection system consisting of granular material and collection piping or a geotextile filter and a geonet with sufficient transmissivity;

- A flexible membrane liner;

- A leak detection system consisting of 12 inches of granular drainage material with hydraulic conductivity of $10^{-2}$ cm/sec or greater or of a geonet with transmissivity of $3 \times 10^{-5}$ m$^2$/sec or more:

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- A flexible membrane liner; and
- A layer of clay 2 to 3 feet thick.

Leachate collection and detection systems would be integral parts of the liner system. The leachate collection and removal system would be supplemented by minimizing water infiltration into the waste cell by the design of the cell cover and by controlling free water within the waste. Prevention of free water within the waste cell could be achieved by controlling the water content of the sludge as it is placed within the cells. As necessary, the free water in the sludge would be adsorbed with a solidification agent prior to disposal. The leachate collection and removal systems would be located inside the lined cell directly above the bottom liner. A leachate detection layer would be located below the leachate collection layer to ensure that leachate does not migrate below the collection layer.

## 4.7   CAP SYSTEM

Some type of cap system placed above the treated sludges will likely be required for closure of the Solar Ponds. The cap system is a physical barrier which will interrupt some exposure pathways. It will also decrease the mobility of contaminants by reducing the potential leaching of contaminants from the sludges.

The cover system acts as an impermeable cap above the waste to isolate the contaminated sludge from the surface environment. The cover would be designed to accommodate any settlement or subsidence within or below the cell. This is achieved by employing flexible materials for cover construction and by controlling processed sludge placement to achieve adequate compaction.

The type of cap required will be a function of the type of treatment performed on the sludges and the resultant characteristics of the final product. Ideally, the treatment technologies selected for the sludge and/or pondcrete will result in delisting, which would minimize requirements for the cap.

If the treated sludge is delisted and does not have characteristics of concern for the protection of human health and environment, it could be placed in the existing ponds and covered as required to reduce infiltration from the surface. If the treated sludge is delisted, but still has characteristics that would be of a concern with respect to protection of human health and the environment, a containment system following the guidelines for a solid waste landfill could be constructed. However, even if the processed sludges are delisted, regulatory considerations may require a cap system designed to meet the requirements for a hazardous waste, or RCRA, landfill cell.

Should hazardous waste cell requirements have to be met, this would represent the worst-case scenario from a cost perspective. The components of a hazardous waste cap typically include the following major components:

- A 2-foot thick soil system consisting of 6 inches of top soil and 1½ feet of general soil fill;
- A geosynthetic filter (optional);
- A biota barrier typically consisting of 1 foot of cobbles (optional);
- A geosynthetic filter;
- A 1-foot thick drainage layer to facilitate removal of water infiltrating the soil cover;
- A composite low-permeability layer consisting of a flexible membrane liner and 2 feet of clay; and
- A gas collection/vent layer to collect and vent any gas that may be generated (optional).

While gas vent layers are usually included to provide control of combustible or toxic gases released from wastes buried in landfill cells, the need for them will not be determined until waste characterization is complete and the final treatment and disposal approaches have been selected.

## 4.8    MONITORING

Following treatment and disposal of the Solar Ponds wastes, long-term monitoring of the disposal site will be necessary to demonstrate the absence of contaminant migration and to

detect any failure of the disposal system. The monitoring options include both ground water monitoring and a variety of direct and indirect vadose zone monitoring techniques.

Ground water monitoring is capable of detecting the presence of contaminants of concern in downgradient ground water. Such an event provides direct evidence of a failure of the disposal system.

Vadose zone monitoring methods allow the detection of a wetting front in a real-time or near real-time manner. An unexpected increase in vadose zone water content may provide early warning of disposal system failure. The direct vadose zone monitoring techniques could include a combination of soil sampling, pore-liquid sampling, and soil gas sampling. Devices such as suction lysimeters and pressure-vacuum lysimeters should be considered. The indirect monitoring techniques could include a combination of neutron probes, capacitance probes, and time domain reflectometry systems.

### 4.8.1 Ground Water Monitoring

RCRA ground water monitoring regulations require that upgradient and downgradient monitoring wells be established. Upgradient monitoring wells serve to provide background ground water quality data in the uppermost aquifer. Upgradient wells must be located beyond the upgradient extent of potential contamination to provide samples representative of background water quality, screened at the same stratigraphic horizon(s) as the downgradient wells to ensure comparability of data, and of sufficient number to account for heterogeneity in background ground water quality.

Downgradient monitoring wells must be located so as to satisfy the regulatory requirements for immediate detection. The placement of downgradient detection monitoring wells must be based upon the abundance, extent, and the physical/chemical characteristics of the potential contaminant pathways.

The site-specific information required to identify the number and location of upgradient and downgradient monitoring wells will be developed during the Solar Ponds RFI/RI that is

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currently underway. Several wells at the Solar Ponds currently serve as monitoring wells. Additional monitoring wells will be installed during the RFI/RI investigations.

### 4.8.2  Direct Vadose Zone Monitoring

Wells and open cavities cannot be used to collect water flowing in the unsaturated zone under suction (negative pressures). The sampling devices for such unsaturated media are thus called suction samplers or lysimeters.

Suction-cup lysimeters are made up of a body tube and porous cup. When placed in the soil, the pores in these cups become an extension of the pore space of the soil. Consequently, the water content of the soil and cup become equilibrated at the existing soil-water pressure by applying a vacuum to the interior of the cup such that the pressure is slightly less inside the cup than in the soil solution, and flow occurs into the cup. The sample is pumped to the surface, permitting laboratory determination of the quality of the soil pore liquid.

Suction cups may be either vacuum operated soil-water samplers or vacuum-pressure samplers. Vacuum samplers are generally used to sample to depths of up to 6 feet from the land surface. Consequently, they are used primarily to monitor the near-surface movement of contaminants from land disposal facilities. Pressure-vacuum systems are recommended for greater depths (to about 50 feet below land surface).

### 4.8.3  Indirect Vadose Zone Monitoring

Potentially applicable indirect vadose zone monitoring techniques considered in this report include neutron moderation, time domain reflectometry, and capacitance probes.

#### 4.8.3.1  Neutron Moderation

Neutron moderation techniques use unstable radioisotopes (usually americium 241 with beryllium) which spontaneously decay and emit fast neutrons. Fast neutrons cannot be detected until they are moderated or slowed by collisions with surrounding atoms, primarily hydrogen in water.

Neutron probe data can be reported as calibrated units of volumetric soil moisture content. This is desirable if data are to be used to estimate soil water and soluble contaminant mobility in conjunction with a known soil water characteristic curve. By measuring soil water content, one can assess the risk of liquid movement. If the soil moisture content in unsaturated soil systems is below a critical level (unique to each system), then the risk of contaminant mobility is nil.

### 4.8.3.2 Time Domain Reflectometry

Time domain reflectometry (TDR) directly measures the velocity of a microwave pulse propagated down a parallel transmission line. The velocity of propagation is dependent on the dielectric constant of the material in contact with and surrounding the transmission line. Since the dielectric constant of water is almost two orders of magnitude greater than the other constituents of soils and sludges, the velocity of propagation of a microwave pulse is highly dependent on the water content. Although soils and sludges have a wide range of particle size distributions, the relationship between the dielectric constant and the water content remains essentially singular. In addition, the bulk density and temperature have no measurable effect on the dielectric constant-water content relationship. The standard error of the estimate for water content for TDR is approximately 1.3 percent by volume.

### 4.8.3.3 Capacitance Probe

The dielectric constant of soil, and thus the volumetric water content, may also be measured in the frequency domain by use of the capacitance method. A capacitance probe measures the capacitance of an electrode system with the dielectric material comprised of the in-situ moist soil surrounding the probe. A capacitor forms part of the feedback loop of a high-frequency oscillatory circuit. Use of the high-frequency oscillator limits the amount of instrument drift due to temperature changes and reduces the contribution of the dipoles to the measured dielectric constant.

Capacitance probes are less than 2 inches in diameter by about 8 inches long. Probes can be buried with leads brought back to a central measurement point. Signal processing units are available for automatic data retrieval, acquisition, and storage. Capacitance probes also

have the advantage that they can be lowered down standard 2-inch PVC well pipe for monitoring water content with depth. Accuracy of the capacitance probes is equivalent to that of TDR instruments.

## 5.0 TREATMENT AND DISPOSAL ALTERNATIVES

The technology options discussed in Section 4.0 can be combined to form a number of treatment and disposal alternatives. Logic diagrams have been developed to illustrate how alternative approaches may be developed in response to technical and regulatory constraints. The potential options that might be derived from the logic diagrams range from approaches as simple as de-watering the sludges in place and closing the ponds without sludge treatment to comprehensive solutions involving removal and treatment of the sludges and containment in a RCRA-type cell.

The following sections discuss the logic diagrams, present an overview of in-place closure, and describe the various in-place closure options involving:

- in-situ de-nitrification;
- disposal requirements;
- liner and cap requirements;
- barrier options;
- cap requirements;
- de-water and cap requirements;
- backfill, cap, and monitoring options;
- pond liner, subsoils;
- water and sludge treatment and disposal options;
- sludge removal and treatment options; and
- pond water and sludge treatment and disposal options.

### 5.1   LOGIC DIAGRAMS

A set of logic diagrams has been prepared to describe the process for selecting in-place closure treatment and disposal alternatives. The logic diagrams use four symbols and a flow indicator to describe the process. The symbols include an oval, a diamond, rectangle, and a dog-eared rectangle, and the flow indicator is an arrow, as shown in Figure 5-1.

Ovals indicate a starting, returning, or terminating point for a logic diagram. A "return" oval indicates that the reader should return to the indicated logic diagram and continue following the logic at the appropriate point on the indicated logic diagram.

Diamonds indicate decision points. "Yes" or "no" responses to the questions in the diamonds define the appropriate flow path to take from the diamond.

Rectangles indicate an action item or a conclusion. An action item can include a design procedure, treatment process, remediation procedure, treatability study, or closure procedure. Dog-eared rectangles indicate an action item that is described further in another logic diagram.

The arrows indicate the flow of logic from one symbol to another. The flow of logic is always toward the arrow head. When more than one arrow exits from a symbol, labels are provided to indicate the appropriate flow path.

## 5.2    IN-PLACE CLOSURE

Figure 5-2 provides an overview of the entire process by which in-place disposal and closure is evaluated as a possibility and by which preferred alternatives are selected. If in-place closure is not possible, offsite disposal strategies will continue to be pursued. If in-place closure is possible, in-situ de-nitrification techniques will be selected and disposal site requirements will be identified as described in Figures 5-3 and 5-4, respectively.

In-place closure is clearly possible from a technical standpoint. Furthermore, existing and proposed environmental regulations applicable to RFP appear to provide the necessary latitude for an in-place closure strategy. As discussed in Section 3, the existing interim status closure regulations require that a unit must be closed in a manner that minimizes the need for further maintenance, controls post-closure escape of contaminants as required to protect human health and the environment, and allows completion of closure activities within 180 days after approval of the closure plan. Extensions to the 180 day closure period

can be obtained if threats to human health and the environment from the site are avoided and all applicable interim status regulations are complied with.

With respect to the need for treatment, interim status surface impoundment closure regulations require that the closure either meet the requirements for either clean closure or closure as a disposal unit (dirty closure). Clean closure is achieved through removal and decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate. The materials removed or decontaminated must be properly handled and disposed of, including potentially disposing of the materials as a hazardous waste. A clean closure would require that contaminants in the remaining soils are below background levels, pose a risk of less than $10^{-6}$, or meet some other soil standard protective of human health and the environment.

Requirements for dirty closure stipulate that free liquids either be removed or solidified, remaining wastes are stabilized to a bearing capacity sufficient to support a final cover for the unit, and a final cover must be designed and constructed to meet specific criteria.

Hybrid closures fall within proposed regulations as a compromise between clean and dirty closures and call for some form of removal and treatment of the waste left in-place, as well as specific long-term monitoring requirements.

In-place closure of the Solar Ponds would likely be a hybrid closure, an approach supported by anticipated regulations.

Whichever strategy is elected, a closure plan must be prepared and amended whenever changes are identified that affect the closure plan. Additionally, if the unit is to be closed as a disposal unit, a post-closure care and monitoring plan is also required.

If treatment of sludges, liners, and subsoils is not required, the ponds and sludges will be de-watered and capped as described in Figure 5-8. If further treatment is required, Figure

5-10 or 5-12 provides the logic for determining the appropriate treatment and disposal processes. The final step for in-place closure will be the implementation of a monitoring program.

## 5.3   IN-SITU DE-NITRIFICATION

Solar Ponds liquids and sludges will likely require in-situ de-nitrification prior to further treatment, as discussed in Section 4.1. Treatability studies should be performed to determined the feasibility of and operating parameters for in-situ de-nitrification as shown in Figure 5-3. If in-situ de-nitrification is shown to be feasible, it will be incorporated into the overall treatment approach.

## 5.4   DISPOSAL SITE REQUIREMENTS

A number of considerations must be addressed to determine the optimal disposal strategy. These considerations include both regulatory and technical issues. Once a determination has been made as to the final disposition of the waste, applicable technical and regulatory requirements can be defined, as shown in Figure 5-4.

Closure under the CAMU concept allows for considerable flexibility with respect to management, movement, and treatment of wastes without necessarily triggering LDRs and MTRs. This is especially true with the expanded CAMU concept.

The current treatment requirements under existing closure standards require proper disposal or decontamination of contaminated structures or equipment. The structures or equipment associated with the closure are considered debris, as discussed in Section 3.4. Prior to land disposal, any hazardous debris must be treated in accordance with waste-specific treatment standards.

The determination of liner, cap, and barrier requirements is illustrated in Figures 5-5 and 5-6.

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## 5.5 LINER AND CAP REQUIREMENTS

The requirement for a containment system incorporating a liner and a cap is common to all the proposed alternatives. Figure 5-5 illustrates the related logic. However, a decision as to what type of containment system will be needed can be made only after a clear understanding of the characteristics of the final treatment products has been obtained and the regulatory constraints are clarified.

A hazardous waste need not be contained in a fully-conforming RCRA cell provided with a liner and cap that meet MTRs if the waste is left in place or treated in place as part of a closure or remedial action. In this case the MTR requirements for liners and leachate collection systems will not apply. However, the facility would have to conform to RCRA requirements for a cap and for groundwater remediation to eliminate threats to human health and the environment.

If liners and contaminated soils are removed for treatment and are then replaced into the location from which they were excavated, the MTR requirements will become effective because these actions create a "new" landfill. These MTRs would require the construction of two or more liners and a leachate collection system above and between the liners.

Proposed rulemaking on CAMUs and expanded CAMUs could give some additional relief from MTR requirements if promulgated. This relief would pertain both to reduced or eliminated capping requirements and potential exemption from liner requirements, even when materials are removed and replaced.

## 5.6 BARRIER OPTIONS

The determination of the need for a barrier system is both a regulatory and technical issue. The logic for barrier options is shown in Figure 5-6. The decision requires an understanding of regulatory alternatives and site hydrogeology. Portions of the Solar Ponds area may, in fact, have an adequate natural vadose zone.

Proposed regulations regarding hybrid closures were published in the Federal Register of March 19, 1987. Since that time no additional rulings or discussions of these proposed rules have been published by the EPA. Hybrid closures combine aspects of closure by removal and closure as a disposal unit. Rather than designing all caps to minimize infiltration and allowing the waste to remain in place, this hybrid approach would consist of the removal of the majority of contaminated materials and would allow covers and post-closure monitoring to be designed based on the pathways of concern. Hybrid closures might be appropriate when the most but not all of the waste will be removed, the residual contamination has low mobility and toxicity, pathways of potential exposures to contaminants are limited, and effective long-term monitoring can be provided.

Hybrid closures would require verification monitoring systems to confirm the predicted fate and transport behavior of the hazardous constituents. The verification monitoring could include leachate collection and analysis, unsaturated zone monitoring, air monitoring, surface water runoff analysis, and groundwater monitoring.

No performance or design criteria, such as minimum acceptable thicknesses of the vadose zone, were specified in the proposed regulations for any aspect of a hybrid closure. Those details were essentially left for the EPA Regional Administrator to determine. It is clear that adequate design of a monitoring system to ensure protection of human health and the environment is a major issue related to hybrid closures.

At the current time there are no RCRA closure-related regulations nor CERCLA site-remediation requirements that directly address the issue of waste in contact with ground water. However, it should be pointed out that ground water which does not meet agency-approved health-based standards, or which otherwise demonstrates an impact from a hazardous waste management unit, is an issue and would require some type of action to ensure that the ground water will meet health-based standards in the future. Thus, a waste, such as a waste vitrified in-place, in contact with otherwise clean ground water does not represent a regulatory problem so long as the waste is not leaching hazardous waste constituents or other contaminants into the ground water.

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Current regulations do not identify a minimum required vadose zone thickness. EPA guidance on unsaturated zone monitoring for hazardous waste land treatment units specifies a minimum thickness of 1 meter.

## 5.7   CAP REQUIREMENTS

As noted above, a hazardous waste does not have to be contained in a RCRA cell provided with a cap that meet MTRs as long as the waste is left in-place or treated in place as part of a closure or remedial action. However, RCRA requirements for a cap and for ground water remediation would still need to be addressed so that the unit does not pose a threat to human health and the environment.

Requirements for a cap or a regulated cap need to be determined, as shown in Figure 5-7, and caps must be designed in accordance with the applicable requirements.

## 5.8   DE-WATER AND CAP

Figure 5-8 shows the actions to be performed to de-water and cap if no further treatment is needed. Excess water will be decanted and treated by the existing process in Building 374 at RFP. Sludges would require further de-watering to have sufficient strength characteristics to support a cap without excessive deformation. After de-watering, sludges would be returned to the pond of origin or consolidated in a common location and compacted. Backfill would be added to create a surface configuration that would facilitate drainage of surface water. A cap would be designed and constructed to reduce surface infiltration and the risk of exposure and contaminant migration.

## 5.9   BACKFILL, CAP AND INSTALL MONITORING SYSTEMS

Figure 5-9 shows actions to be performed after the waste has been treated and deposited in a pond or cell. Appropriate imported materials will be used as backfill to bring the disposal area up to grade. The area will then be capped, and monitoring systems will be installed.

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Monitoring requirements only pertain to those RCRA units that are closed as a disposal unit. If closed as a disposal unit, ground water monitoring requirements include at least one upgradient well and at least three downgradient wells. However, the number of wells must be sufficient to adequately characterize ground water and protect human health and the environment. If the unit is clean-closed, no further monitoring is required. Hybrid closure would require long-term monitoring.

## 5.10   POND LINERS, SUBSOILS, WATER AND SLUDGES TREATMENT AND DISPOSAL

Figure 5-10 shows the actions to be performed to treat and dispose of the pond liners, subsoils, pond water and sludges. Excess water will be decanted and treated by the existing process in Building 374 at RFP. A determination as to whether deep treatment is required will depend on results from the soil characterization being performed as part of the Phase I RFI/RI investigation.

If the subsoils require deep treatment, studies will be performed to determine the most appropriate deep solidification technology. After a solidification technology has been established, the need for a barrier will be determined as shown in Figure 5-6. Following completion of deep solidification, backfill will be added, a cap will be constructed, and monitoring systems will be installed as described in Figure 5-9.

If the subsoils do not require deep treatment, the pond sludges will be removed and treated as described in Figure 5-11. Next the liner and subsoils will be excavated and reduced or screened. If the oversized debris material needs to be treated, an appropriate treatment will be performed based upon the results of treatability studies. The treated debris waste stream will be disposed with the treated sludge. Treatment studies will need to be performed on the liner and subsoil waste to determine a desirable soil-like solidification chemistry. Once a satisfactory solidification technology has been identified, the liner and subsoil waste will be solidified. The solidified waste will then be disposed into an area where a barrier and liner have been constructed as previously determined in Figures 5-5 and 5-6. Backfill will be added, a cap will be constructed, and monitoring systems will be installed as described in Figure 5-9.

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## 5.11    SLUDGE REMOVAL AND TREATMENT

Sludges will be removed and treated as required, as shown in Figure 5-11.  Staging will be required if a liner must be installed or upgraded or if a barrier system must be constructed. If staging of treated sludges is required, the sludges will be de-watered to a high-solids content and solidified to a soil-like consistency to facilitate subsequent handling and compaction by conventional bulk material equipment and methods.  All water will be treated by the existing process in Building 374 at RFP.  The sludge will be deposited after the barrier and liner have been prepared as determined in Figures 5-5 and 5-6.  Backfill will be added, a cap will be designed and constructed, and monitoring systems will be installed as described in Figure 5-9.

If staging is not required and treated sludges can be directly redeposited in the pond of origin or consolidated in a common location, the sludges will be de-watered to a solids content of approximately 20 percent and solidified using a chemistry similar to that identified by Halliburton\NUS.  All water will be treated by the existing process in Building 374 at RFP.  The solidified sludge will then be disposed into an area where a barrier and liner have been constructed as previously determined in Figures 5-5 and 5-6.  Backfill will be added, a cap will be constructed, and monitoring systems will be installed as described in Figure 5-9.

## 5.12    POND WATER AND SLUDGE TREATMENT AND DISPOSAL

Figure 5-12 shows the actions to be performed to treat and dispose of the pond water and sludges.  Excess water will be decanted and treated by the existing process in Building 374 at RFP.  If in-situ solidification is not desired, the pond sludges will be treated as described in Figure 5-11.

If in-situ solidification will be performed and the treated sludge will be left in the pond of origin, then the sludges will be de-watered to a solids content of approximately 20 percent and solidified using a chemistry similar to that identified by Halliburton\NUS.  All water will be treated by the existing process in Building 374 at RFP.  Backfill will be added, a cap

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will be designed and constructed, and monitoring systems will be installed as described in Figure 5-9.

If in-situ solidification is performed and the treated sludge will not be left in the pond of origin, then treatability studies will be required to determine a desirable soil-like solidification chemistry. The sludges will then be de-watered to a high-solids content and solidified to a soil-like consistency. All water will be treated by the existing process in Building 374 at RFP. The sludge will be deposited in a desirable location as previously determined in Figure 5-4 after a barrier and liner have been prepared as previously determined in Figures 5-5 and 5-6. Backfill will be added, a cap will be constructed, and monitoring systems will be installed as described in Figure 5-9.

Sludge washing has not been included in the above discussion because of technical uncertainties as to its applicability to Solar Ponds sludges. Should treatability studies demonstrate its effectiveness, sludge washing should be considered as a potential initial treatment process to reduce the volume of waste requiring treatment.

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# 6.0 CONCLUSIONS

Several conclusions can be drawn from this preliminary analysis of treatment and disposal options for in-place closure of the Solar Ponds. They relate to the Solar Ponds status, technical feasibility of in-place closure, and regulatory constraints.

## 6.1 STATUS OF THE SOLAR PONDS

Solar Ponds 207B-North, 207B-Center, 207B-South, and 207C currently contain liquids and sludges originating from process wastes and contaminated ground water from the ITS. The lack of a permitted offsite disposal facility has so far precluded transportation of the solidified sludges and sediments to a disposal facility. In-place closure offers an attractive, cost effective alternative to the originally planned offsite disposal.

## 6.2 TECHNICAL FEASIBILITY

In-place closure of the Solar Ponds is clearly achievable from a technical standpoint. A number of available treatment and disposal technologies are available for Solar Ponds wastes. These technologies include de-nitrification, decanting/de-watering, solidification/stabilization, barriers, liners, caps, and monitoring. Logic diagrams presented in this report show how these technology options can be combined to form a number of treatment and disposal alternatives.

While a considerable amount of additional information must be gathered before a preferred alternative can be selected and a closure plan can be prepared, in-place closure could be achieved through a sequence of steps involving de-nitrification, decanting of pond liquids and de-watering of the remaining sludges, evaporation of the water in Building 374, solidification of the sludges, replacement of the solidified sludge in re-lined Solar Ponds, capping the disposal cell, and long-term monitoring. Barriers may be required to maintain an adequate vadose zone. It may also be possible to incorporate and treat the existing pondcrete with the sludges.

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## 6.3    REGULATORY CONSTRAINTS

Remedial activities at the Solar Ponds must be conducted in a complex regulatory environment of multiple laws, regulations, and enforcement authorities. In-place closure of the Solar Ponds would require, at a minimum, consideration of regulations promulgated under RCRA, CERCLA, NEPA, DOE orders, and various Colorado environmental laws. The complexity of this regulatory framework is exacerbated by proposed and anticipated changes to the regulations and by their modification through negotiation.

Of particular importance to the viability of in-place closure are proposed regulations relating to Corrective Action Management Units and hybrid closures. A hybrid closure coupled with application of the CAMU concept has the potential to significantly reduce the cost and logistical difficulty of remedial activities at the Solar Ponds.

## 6.4    PREFERRED ALTERNATIVES

Selection of a preferred alternative will require a detailed understanding of the Solar Ponds wastes, the extent of contamination of the Solar Pond liners and underlying soils, the site hydrogeology, and the regulatory environment. Currently, none of these are adequately characterized. However, it is possible to present an in-place closure option most likely to succeed in the face of existing and anticipated technical and regulatory requirements, assuming the following:

- A hybrid closure concept is approved by the regulatory agencies;
- The regulatory agencies approve the Solar Ponds as a CAMU; and
- Pond 207A has a permanent vadose zone of at least one meter.

The preferred option would include:

- In-situ de-nitrification;
- De-watering;
- Sludge removal;
- Ex-situ solidification;
- Re-lining of Pond 207A with FML;
- Disposal of Pond 207B stabilized sludge slurries in one portion of Pond 207A;

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- Disposal of Pond 207C stabilized sludge slurry in the remaining portion of Pond 207A;

- Placement of a RCRA cap on Pond 207A;

- Monitoring of the vadose zone and ground water at Pond 207A; and

- Backfilling and capping the 207B ponds and Pond 207C.

It must be noted, however, that many details require further clarification before any specific recommendation can be made.

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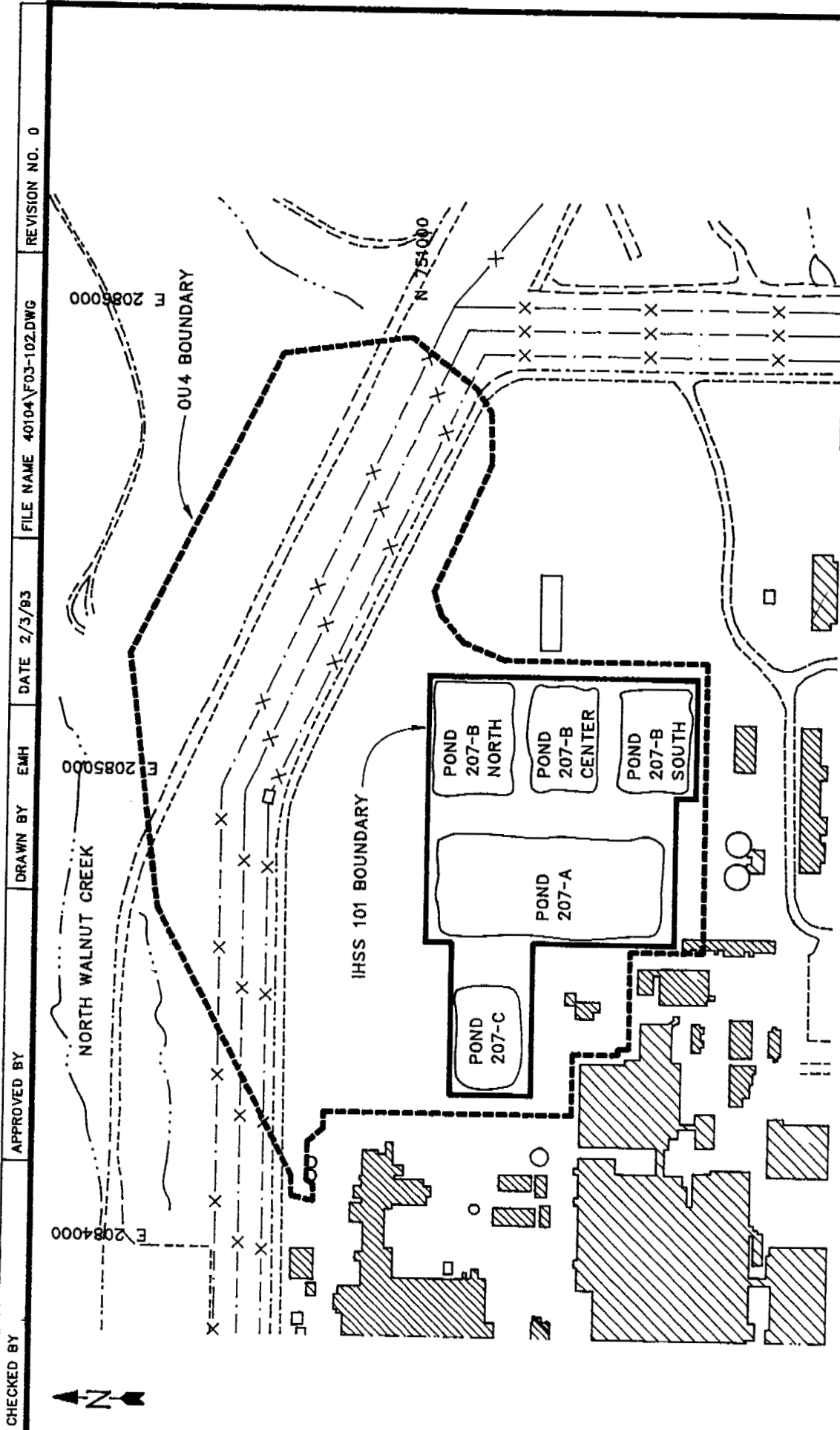
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FIGURE 1-1
SITE PLAN
SOLAR PONDS – OU4

CHECKED BY | APPROVED BY | DRAWN BY EMH | DATE 2/3/93 | FILE NAME 40104\F03-102.DWG | REVISION NO. 0

OU4 BOUNDARY

E 2086000

N 754000

E 2085000

NORTH WALNUT CREEK

E 2084000

IHSS 101 BOUNDARY

POND 207-B NORTH
POND 207-B CENTER
POND 207-B SOUTH
POND 207-A
POND 207-C

PONDCRETE STORAGE AREA

150    0    150    300 FEET

N

Starting or
Terminating Point

Decision Point

Action Item shown in
separate logic diagram

Action Item

Flow Indicator
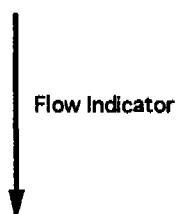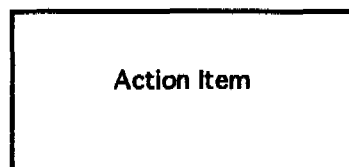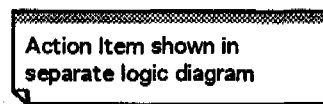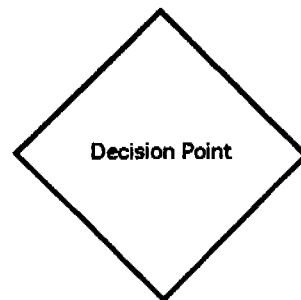
**FIGURE 5-1**

**Legend for Logic Diagram**

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START

In Place Closure Possible?

no → Consider offsite alternatives

yes

In-situ De-nitrification (See Figure 5-3)

Identify Disposal Site Requirements (See Figure 5-4)

Further treatment needed?

no → De-Water and Cap (See Figure 5-8) → Monitor

yes

Do liner and subsoils need treatment?

no → Treat and Dispose Pond water and sludges (See Figure 5-10) → Monitor

yes

Treat and Dispose Pond Liners, sub soils, water and sludges (See Figure 5-12)

Monitor
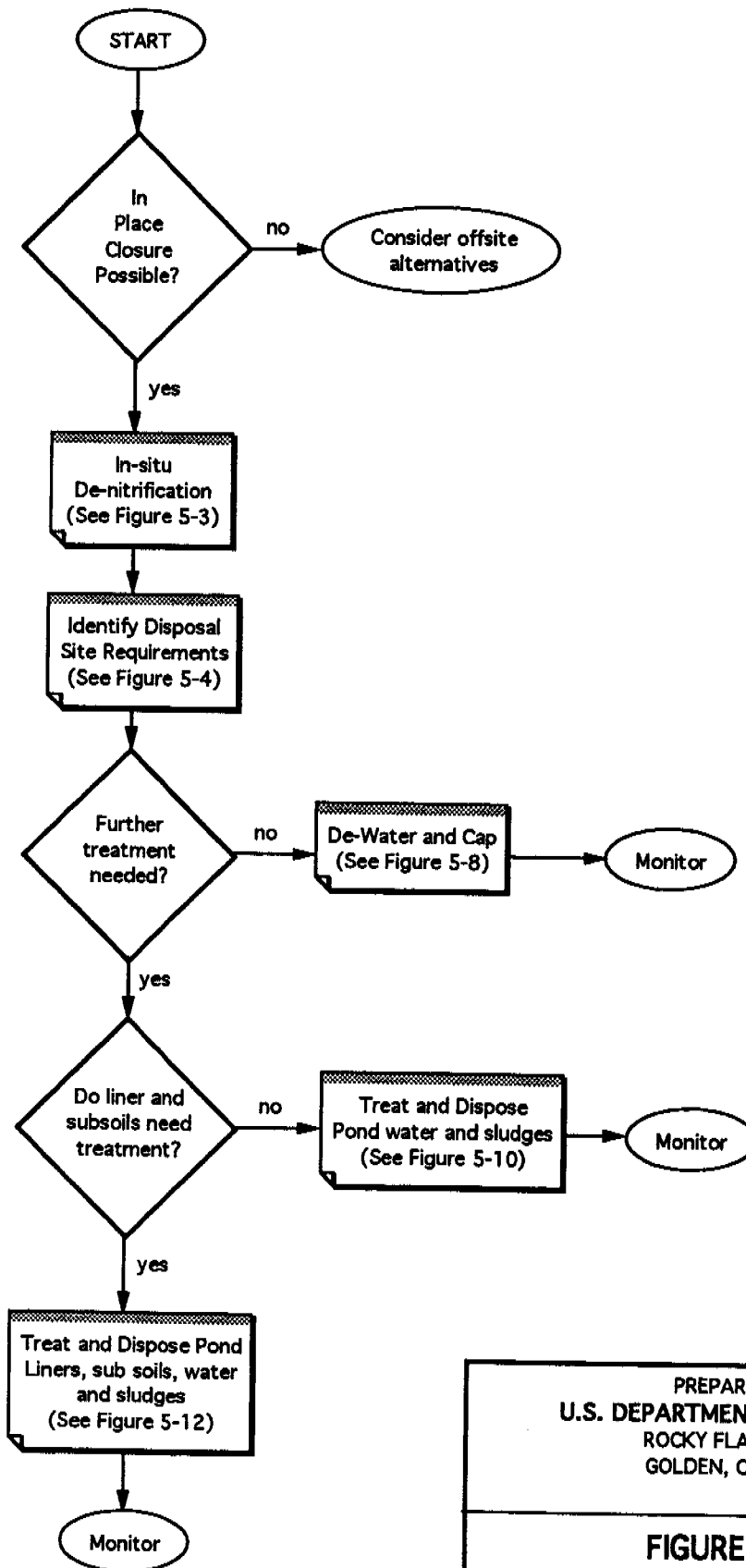
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**FIGURE 5-2**

**In-Place Closure Logic**

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                          ┌─────────┐
                          │  START  │
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                     │  Perform In-situ │
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                     │      Studies     │
                     └─────────┬────────┘
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                           ◇ it feasible? ◇ ────────────▶│ RETURN TO FIGURE 5-2  │
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                               │ yes
                               ▼
                     ┌──────────────────┐
                     │  Perform In-situ │
                     │  De-nitrification│
                     └─────────┬────────┘
                               │
                               ▼
                     ╭──────────────────────╮
                     │  RETURN TO FIGURE 5-2 │
                     ╰──────────────────────╯
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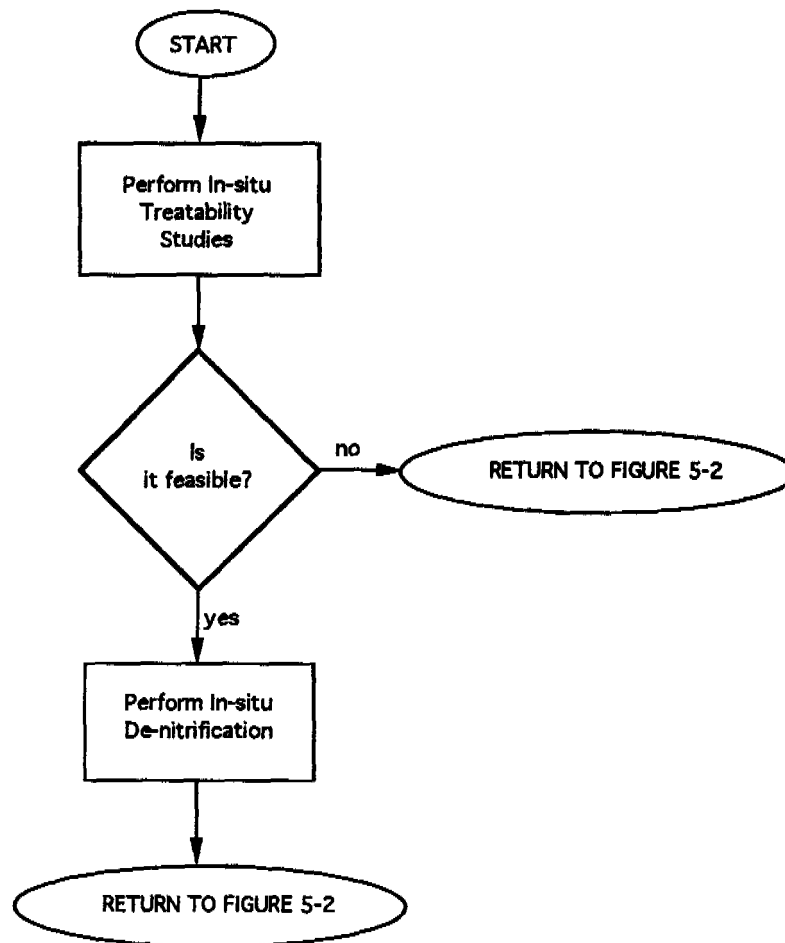
**FIGURE 5-3**

**In-situ De-Nitrification Logic**

START

Dispose in Pond of Origin?

no → Determine Disposal Site

yes

Determine applicable Disposal Requirements

Determine Liner and Cap Requirements (See Figure 5-5)

Determine and Design Barrier Options if necessary (See Figure 5-6)

RETURN TO FIGURE 5-2
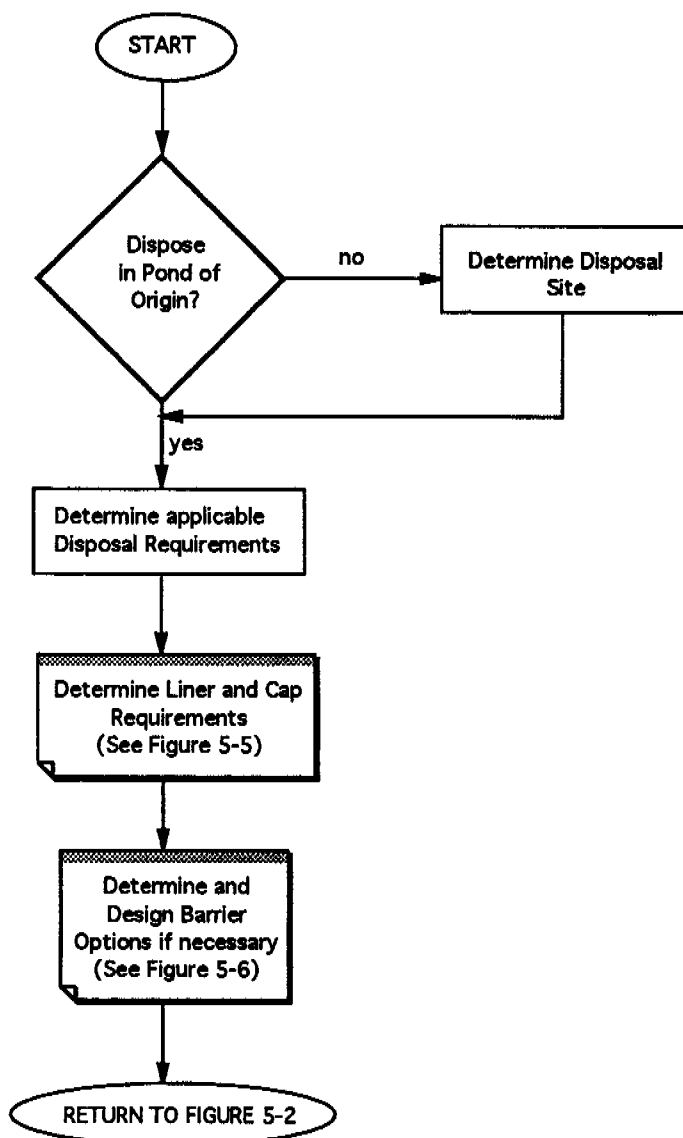
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**FIGURE 5-4**

**Disposal Site Requirements**

```
                    ┌─────────┐
                    │  START  │
                    └────┬────┘
                         │
                         ▼
                      ╱╲
                     ╱  ╲
                    ╱ New ╲        no
                   ╱ liner ╲──────────────────────────────┐
                   ╲needed? ╱                              │
                    ╲      ╱                               │
                     ╲    ╱                                │
                      ╲  ╱                                 │
                       ╲╱                                  │
                        │ yes                              │
                        ▼                                  │
                      ╱╲                                   │
                     ╱  ╲                                  │
                    ╱Regula╲    no    ┌──────────────┐     │      ┌──────────────┐          ┌─────────────────────┐
                   ╱ -ted   ╲────────▶│   Design     │─────┼─────▶│ Determine Cap│─────────▶│ RETURN TO FIGURE 5-4│
                   ╲ liner  ╱         │ appropriate  │     │      │ Requirements │          └─────────────────────┘
                    ╲needed?╱         │    liner     │     │      │(See Figure 5-7)│
                     ╲     ╱          └──────────────┘     │      └──────────────┘
                      ╲   ╱                                │
                       ╲ ╱                                 │
                        │ yes                              │
                        ▼                                  │
                 ┌──────────────┐                          │
                 │Design regulated│                        │
                 │    liner      │                         │
                 └──────┬───────┘                          │
                        └─────────────────────────────────┘
```
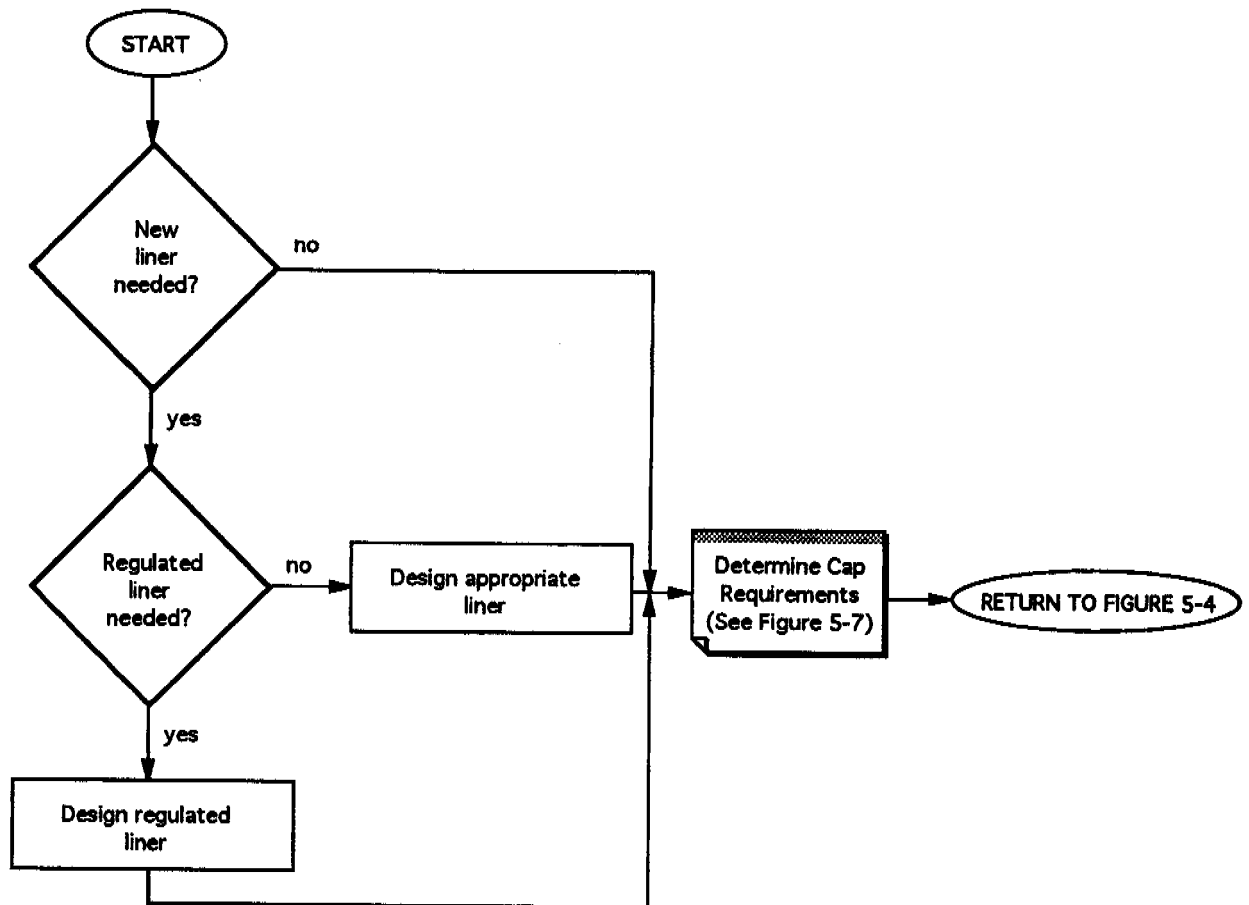
**FIGURE 5-5**

**Liner and Cap Requirements Logic**

START

Is Hybrid Closure Possible? —no→ Is Groundwater contact a problem? —no→ no barrier → RETURN TO FIGURE 5.4

yes ↓

Is the Vadose Zone Sufficient? —no→ Design Groundwater barrier → RETURN TO FIGURE 5.4

yes ↓ (Groundwater contact) yes ↓

no barrier

↓

RETURN TO FIGURE 5.4
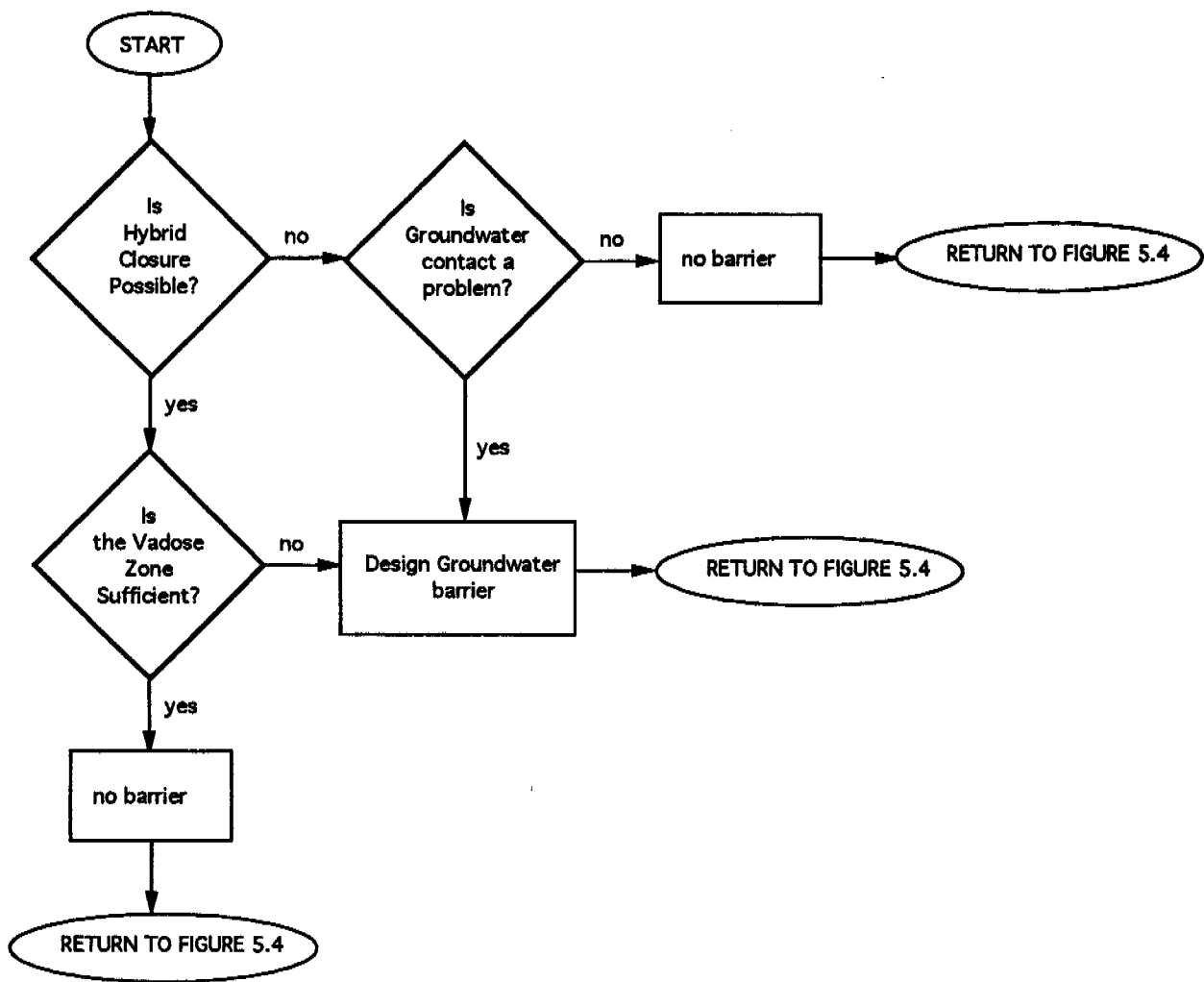
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ROCKY FLATS PLANT
GOLDEN, COLORADO

**FIGURE 5-6**

**Barrier Options Logic**

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START

Cap needed? — no → RETURN TO FIGURE 5-5

yes

Regulated cap needed? — no → Design appropriate cap → RETURN TO FIGURE 5-5

yes

Design regulated cap

RETURN TO FIGURE 5-5
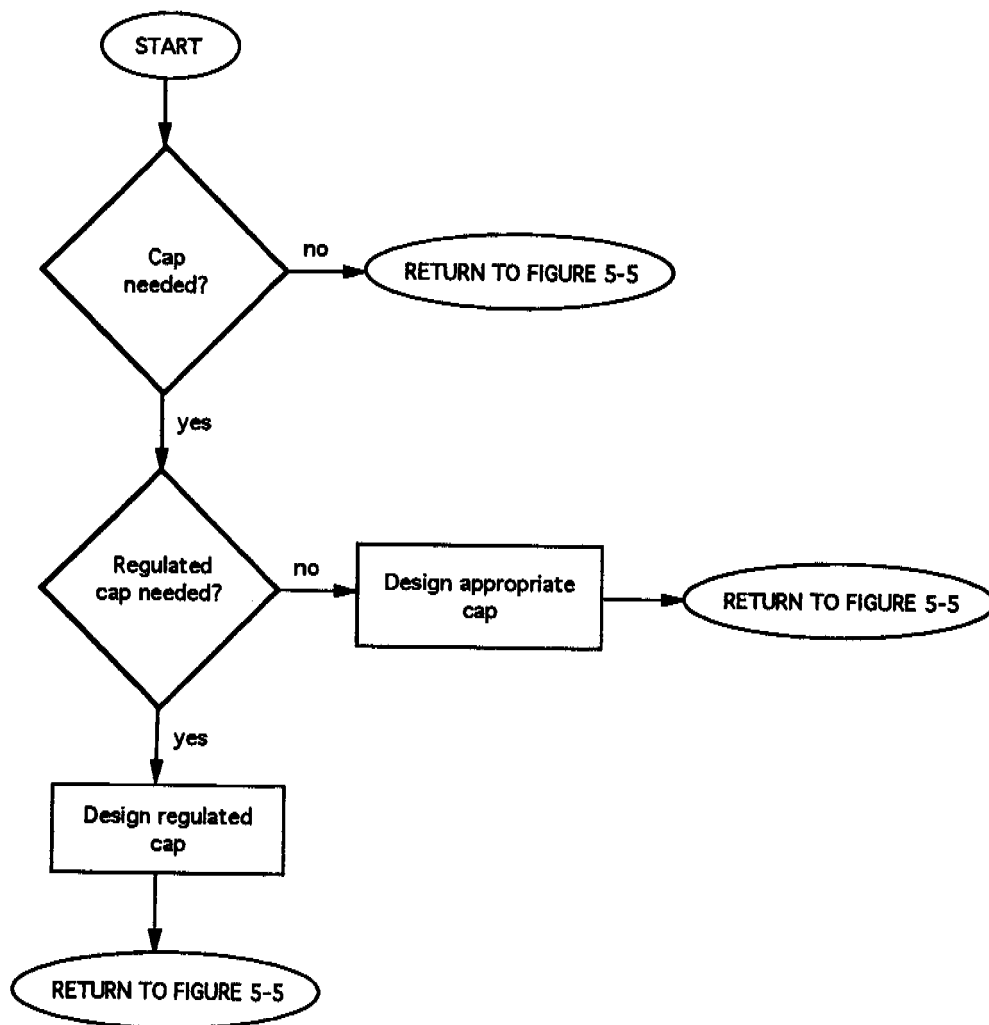
PREPARED FOR
**U.S. DEPARTMENT OF ENERGY**
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GOLDEN, COLORADO

**FIGURE 5-7**

**Cap Requirements Logic**

```
                              ┌──────────┐
                              │  START   │
                              └────┬─────┘
                                   │
                                   ▼
          ┌───────────────┐      water      ┌───────────────┐
          │    Decant     │───────────────▶ │  Building 374 │
          └───────┬───────┘                 └───────────────┘
                  │                                  ▲
                  ▼                                  │
          ┌───────────────┐                          │ water
          │ Remove sludge │                          │
          └───────┬───────┘                          │
                  │                          ┌───────────────┐
                  ▼                   no      │ De-water sludge│
             ╱─────────╲  ──────────────────▶└───────┬───────┘
            ╱ Staging of ╲                            │ sludge
           ╱   sludge     ╲                           ▼
           ╲  required?   ╱                ┌─────────────────────────┐
            ╲            ╱                 │ Dispose Sludge into an   │
             ╲──────────╱                  │ area where a barrier and │
                  │ yes                     │ liner have been          │
                  ▼                         │ constructed as           │
   ┌──────────────────────────┐             │ previously determined    │
   │ Construct Barrier and Liner│            └────────────┬────────────┘
   │ as previously determined  │                          │
   └─────────────┬─────────────┘                          │
                 │                                         │
                 ▼                                         │
┌─────────────┐ water ┌───────────────┐                   │
│ Building 374│◀──────│ De-water sludge│                  │
└─────────────┘       └───────┬───────┘                   │
                              │ sludge                     │
                              ▼                            │
                      ┌───────────────┐                    │
                      │Dispose of Sludge│                  │
                      └───────┬───────┘                    │
                              │◀───────────────────────────┘
                              ▼
                  ┌───────────────────────────┐
                  │ Backfill, Cap and         │
                  │ Install Monitoring Equipment│
                  │ (See Figure 5-9)          │
                  └─────────────┬─────────────┘
                                │
                                ▼
                      ┌─────────────────────┐
                      │ RETURN TO FIGURE 5-2 │
                      └─────────────────────┘
```
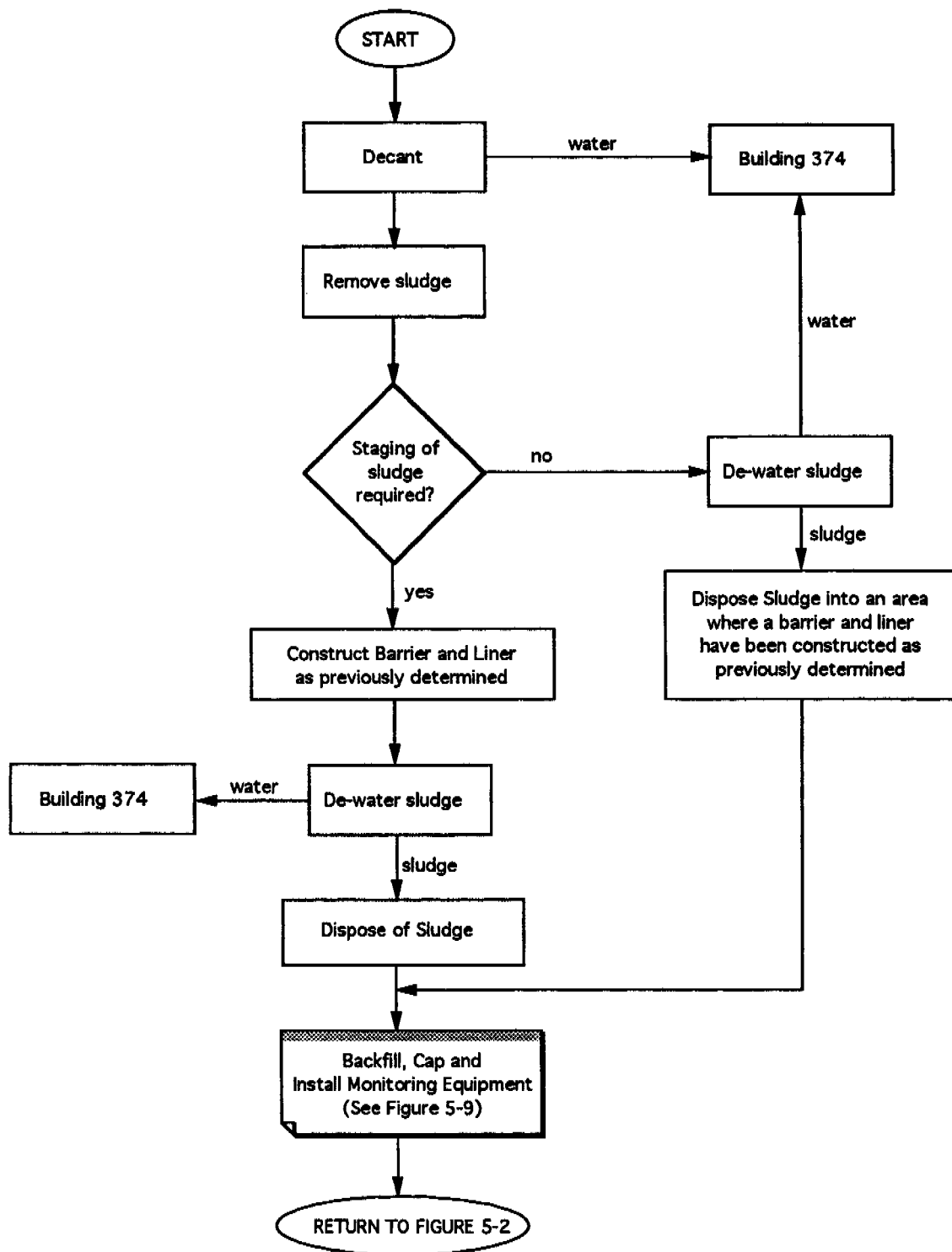
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ROCKY FLATS PLANT
GOLDEN, COLORADO

## FIGURE 5-8

**De-Water and Cap Logic**

START

Backfill with appropriate
material as required to
bring up to grade

Construct Cap as
previously determined

Install
Monitoring Equipment

Return to Figure 5-8
or Figure 5-10
or Figure 5-11
or Figure 5-12
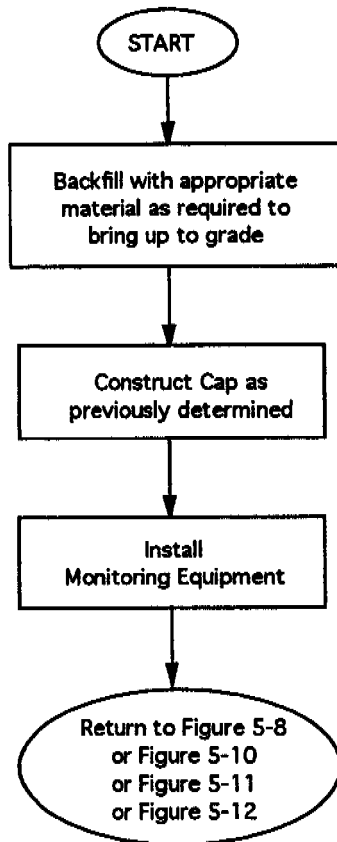
## FIGURE 5-9

**Backfill, Cap and Install
Monitoring Systems Logic**
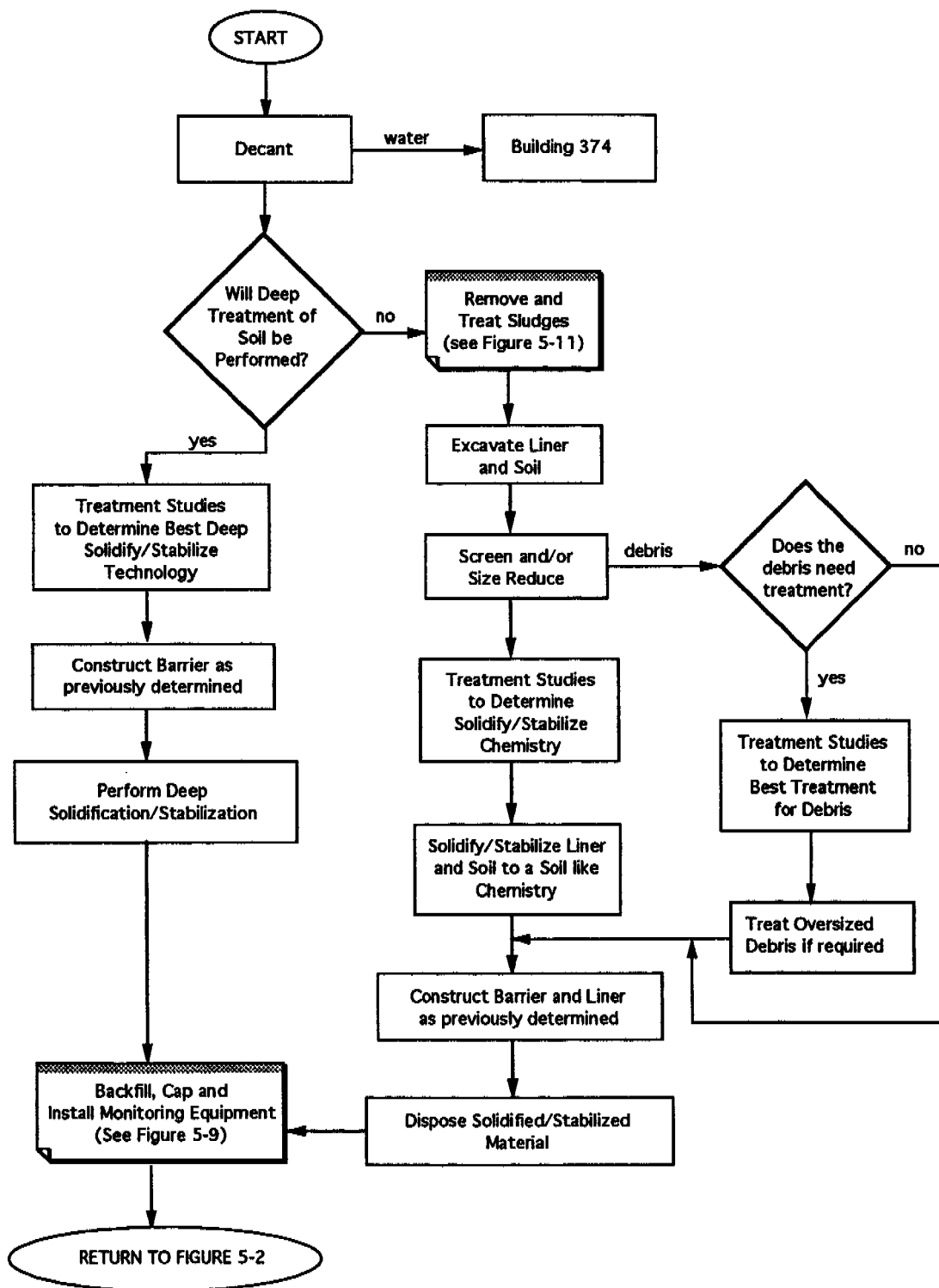
FIGURE 5-10
Pond Liners, Subsoils, Water
and Sludges Treatment
and Disposal Logic

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GOLDEN, COLORADO

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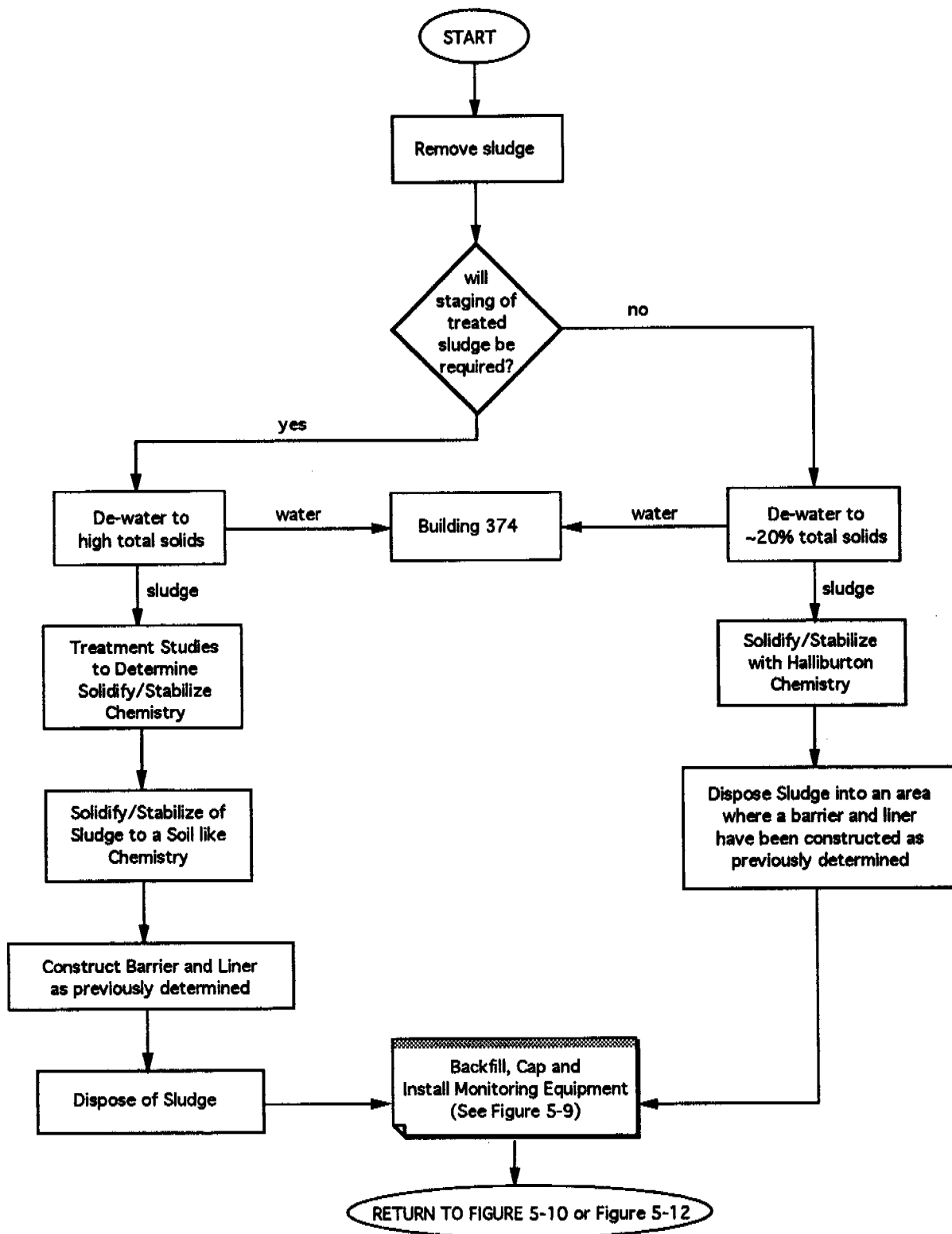
FIGURE 5-11

Sludge Removal and Treatment Logic

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GOLDEN, COLORADO

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START

Decant ——water——▶ Building 374

S/S
of sludges
In-situ? ——no——▶ Remove and
Treat Sludges
(See Figure 5-11) ——▶ RETURN TO FIGURE 5-2

yes

Will
treated
sludges be
left
in place? ——no——▶ Treatment Studies
to Determine
Solidify/Stabilize
Chemistry

yes

De-water to
~20% total solids ——water——▶ Building
374 ◀——water—— De-water as
required

sludge                                                sludge

Solidify/Stabilize
with Halliburton
Chemistry                                   Solidify/Stabilize of
Sludge to a Soil like
Chemistry

Construct Barrier and Liner
as previously determined

Backfill, Cap and
Install Monitoring Equipment
(See Figure 5-9) ◀—— Dispose of Sludge

RETURN TO FIGURE 5-2

FIGURE 5-12

Pond Water & Sludge
Treatment and Disposal Logic

**APPENDIX A**

**OU4 HISTORICAL DATA SUMMARY**

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# APPENDIX A

## OU4 HISTORICAL DATA SUMMARY

The Solar Ponds area has been the subject of numerous subsurface investigations to determine various physical and chemical contamination characteristics of the area. The following chronology lists some of the more pertinent data regarding the characterization of subsurface geologic, hydrogeologic, and chemical contamination conditions in the Solar Pond area.

1954 -  A well was drilled off the northeast corner of the original clay-lined Solar Pond to a depth of approximately 16 feet. The well did not produce water and was apparently backfilled immediately.

1960 -  Six wells were installed around the Solar Ponds, with emphasis on the Pond 207B area. Water quality data (pH, gross alpha activity, nitrate concentration, specific gravity, and depth to water) from these wells is available in monthly history/progress reports up to approximately 1970. Limited analyses of water from these wells also exist from 1970 to the early 1980s. Borehole logs for these wells are not known to exist. A natural gamma and a neutron (geophysical) log for hole 4-60 are available. These wells were abandoned in the recent well abandonment program.

1966 -  Wells 2-66 and 3-66 were completed near the Solar Ponds in alluvium and bedrock materials. Construction details and lithologic logs for these two holes are reportedly available.

1970 -  A geologic and subsoil investigation at the Solar Ponds was conducted to evaluate landslide potential north of the Solar Ponds. Ten boreholes were drilled to determine subsoil and ground water conditions. Completion data and general lithologic logs are available for these wells.

1971 -  Well 6-71 was completed due north of Pond 207A near the old perimeter road. The total depth of this well is approximately 61 feet, but no lithologic log is known to exist. This well was recently abandoned as part of the well abandonment program.

1974 -  A Dow Chemical study was conducted that involved analysis of numerous soil samples for nitrate. The samples were obtained from fifty-six boreholes in three distinct areas north of the Solar Ponds. Most of these boreholes were terminated approximately 12 to 13 feet below the soil surface. Each of the three areas had borings 25 feet apart in rows. The rows varied in each area from 25 to 100 feet apart. Lithologic logs of these holes are not available.

1975 -  An Engineering-Science report presented the results of a 31-hole boring program to investigate the presence of nitrate contamination near the Solar Ponds. The depth of these holes varied. They were located in a rough grid

pattern over the northeast portion of the site. Limited cross-sectional data is presented in the report, but lithologic logs were not included in the report. Ground water was analyzed for nitrate in this study.

1986 -    Installation of a RCRA-quality ground water monitoring system began at RFP. Data are reported in Section E (Volume VI & VII) of the RCRA Part B Permit Application of November 28, 1986. These data include lithologic logs, completion information, and aquifer tests. Approximately twenty-two of the wells (some well pairs) from the 1986 program were installed in the OU4 project area. Some brief conclusions from that study include:

- Single-hole pump tests indicated $10^{-3}$ cm/sec hydraulic conductivity in the Rocky Flats alluvium. None of the wells was in the OU4 area;

- The hydraulic conductivity was estimated to be $10^{-6}$ cm/sec based on drawdown recovery tests, but no distinction was made between silty claystones and claystones;

- Packer tests were performed at various levels in approximately 18 wells at RFP. Some of the wells (14-86, 15-86, 16-86, 17-86, 22-86, 25-86, 27-86, 32-86) are located within the OU4 area. The geometric mean hydraulic conductivity is $2 \times 10^{-6}$ for the Arapahoe sandstone, $5 \times 10^{-7}$ for weathered Arapahoe claystone, $1 \times 10^{-7}$ for unweathered Arapahoe claystone, $7 \times 10^{-5}$ for Rocky Flats alluvium, and $2 \times 10^{-2}$ for valley fill, all in cm/sec;

- It is believed that no chemical or physical tests were conducted on core soils from the 1986 wells; and

- Some of these holes were relogged due to questions regarding the accuracy of the logging.

1987 -    Seventeen boreholes were installed in the Solar Pond area to investigate chemical conditions in the soils. These boreholes were not completed as wells. Borehole logs and chemical analyses of the soil samples are available. Some of these holes may have been relogged due to questions regarding the accuracy of the logging.

1988 -    In the course of revising the RCRA closure plan for the Solar Ponds, a fairly detailed evaluation of the site was conducted using all data available at that time except the well water analyses from the 1960s.

1989 -    The subsurface investigation proposed in the 1988 Solar Pond Closure Plan and other characterization work were implemented in the Solar Pond area. This work included the completion of approximately 32 wells in the Solar Ponds area. Boreholes that were not completed as wells may also have been drilled. The sandstones that the 1988 program had been designed to specifically investigate were not found in any of the 1989 holes. This called

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into question the accuracy of the 1986 and 1987 borehole logs. Some core samples were then compared to the logs and significant errors were found. This prompted the overall site geologic characterization activities which involved relogging many of the previously completed holes.

1990 - A geotechnical investigation was conducted in the 881 Hillside ITS area (now OU1). This study is pertinent to the Solar Pond area because it focused on part of the Arapahoe claystone which is thought to be similar site-wide. Both aquifer testing and geotechnical testing of the claystone materials were performed.

1991/1992 - As a part of the site-wide geologic characterization, four boreholes were drilled in the OU4 area. Lithologic logs for these holes were developed in extreme detail. Chemical analyses were conducted on soil samples from the cores at these holes.

1991/1992 - As a part of the well abandonment and replacement program, all the pre-1986 wells were abandoned. Some of the pre-1986 wells were replaced with new wells. Logs of the new wells were created. These activities were in conjunction with the site-wide geologic characterization study.

1992 - Preliminary Investigation on Potential Leakage from the 207B Solar Evaporation Ponds, July 13, 1992

This report detailed the activities of a brief investigation addressing whether the 207B ponds were leaking into the uppermost aquifer. This was done by sampling wells in the Solar Pond vicinity for a dye that was, and is, present in the Solar Ponds. The wells that were sampled collected water in both the alluvium and the silty claystones of the Arapahoe. Based on this study, no leakage was occurring from the 207B ponds.

1992 - Phase II RFI/RI Aquifer Test Report, Draft Final (for OU2), August 14, 1992

Pumping tests were performed at three sites within OU2 and yielded data on the Arapahoe sandstone and Rocky Flats alluvium. The results of the tests indicated hydraulic conductivity of $4 \times 10^{-4}$ cm/s for the Arapahoe sandstone and from $2 \times 10^{-4}$ to $5 \times 10^{-5}$ cm/s for the Rocky Flats alluvium. Longitudinal dispersivity for the sandstone was reported as 0.19 ft and for the alluvium as 1.95 ft. Kinematic (effective) porosity was 12 percent for the sandstone and 0.3 percent for the alluvium.

The Arapahoe sandstone in the test site of OU2 existed as an unconfined aquifer. Saturated alluvium overlies the Arapahoe sandstone where the test was performed, and they were hydraulically connected.

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1992 -      Phase II Geologic Characterization Data Acquisition Packer Injection Test Report, October 14, 1992

This report was one phase of the evaluation of geologic characteristics at RFP. Packer injection testing of selected intervals in boreholes was performed to obtain estimates of the aquifer characteristics of the tested formations. Ten constant-head injection tests and one falling-head injection test were conducted at seven boreholes to isolate and test bedrock formation materials. Four of the boreholes were located approximately 4,000 feet north of OU4 in geologic materials similar to those found at OU4. The results of these tests indicated that hydraulic conductivities ranged from $1 \times 10^{-6}$ to $4 \times 10^{-8}$ cm/sec in bedrock materials. EG&G personnel are continuing the evaluation of overall geologic characterization data.

1992 -      Draft Final, Phase III RFI/RI Report for OU1 [the 881 Hillside] October 1992

This fourteen-volume report contains considerable data (lithologic logs, many types of hydraulic conductivity tests, evaluation of contaminant movement, geotechnical soil analyses, chemical soil analyses, along with some modeling) on materials similar to those found in the OU4 area. OU1 is approximately 3,000 feet south of OU4 on the south slope of the same mesa on which the Solar Ponds are located.

**APPENDIX B**

**SOLAR PONDS WASTE CHARACTERISTICS**

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## TABLE 2.7

## SOLAR EVAPORATION POND 207A
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

| Compound | Units | 207A Liquid | | 207A Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| ANIONS | | | | | |
| Ammonia | ppm | NA | 0.43 | NA | NA |
| Bicarbonate | ppm | NA | 35 | NA | NA |
| Carbonate | ppm | NA | 47 | NA | NA |
| Chloride | ppm | NA | 416 | NA | NA |
| Cyanide, Total | ppm | ND - 1.7 | 0.478 | NA | NA |
| Fluoride | ppm | NA | ND | NA | NA |
| Nitrate, N | ppm | ND - 21,739 | 1000 | 8800 | NA |
| Nitrite | ppm | NA | 39 | NA | NA |
| Phosphate, Ortho | ppm | NA | ND | NA | NA |
| Phosphate, Total | ppm | NA | ND | NA | NA |
| Sulfate | ppm | NA | 409 | NA | NA |
| Sulfide | ppm | NA | ND | NA | NA |
| TKN-N | ppm | NA | ND | NA | NA |
| RADIONUCLIDES | | | | | |
| Americium -241 | pCi/l | ND - 200 | 0.42 | NA | NA |
| Americium -241 | pCi/g | NA | NA | 1400-4400 | NA |
| Plutonium -239 | pCi/l | ND -660 | 0.71 | ND | NA |
| Plutonium -239 | pCi/g | NA | NA | 1000-3700 | NA |
| Uranium -234 | pCi/l | 14000-20000 | 310 | NA | NA |
| Uranium -234 | pCi/g | NA | NA | 70-570 | NA |
| Uranium -235 | pCi/l | NA | 11 | 28-28 | NA |
| Uranium -235 | pCi/g | NA | NA | 28-28 | NA |
| Uranium -238 | pCi/l | 21000-28000 | 340 | 520-520 | NA |
| Uranium -238 | pCi/g | NA | NA | 130-480 | NA |

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## TABLE 2.7

### SOLAR EVAPORATION POND 207A
### SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

**(continued)**

| Compound | Units | 207 A Liquid | | 207A Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| Uranium | pCi/l | 0.7-26000 | ND | NA | NA |
| Tritium | pCi/l | 240-3000 | NA | NA | NA |
| Tritium | pCi/g | NA | NA | 1300-12000 | NA |
| Gross Alpha | pCi/l | 32-80000 | 300 | NA | NA |
| Gross Beta | pCi/l | 2-40000 | 930 | NA | NA |
| MISCELLANEOUS | | | | | |
| Alkalinity, Total | ppm | NA | 110 | NA | NA |
| Conductivity @25C | uMHOs | NA | 8800 | NA | NA |
| Total Dissolved Solids | ppm | 127000-127000 | 7600 | NA | NA |
| Total Organic Carbon | ppm | NA | 67.8 | NA | NA |
| Total Suspended Solids | % | NA | 23 | NA | NA |
| pH | ppm | 8.3-11 | 9.9 | 9.5 | NA |
| METALS | | | | | |
| Aluminum | ppm | 2.31-2.64 | ND | 11000-11900 | NA |
| Antimony | ppm | NA | ND | NA | NA |
| Arsenic | ppm | 0.015-0.015 | ND | ND | NA |
| Barium | ppm | ND | NA | ND | NA |
| Beryllium | ppm | ND-0.1 | NA | 309-1570 | NA |
| Biosmuth | ppm | NA | ND | NA | NA |
| Boron | ppm | NA | 1.26 | NA | NA |
| Cadmium | ppm | 0.070-0.150 | ND | 1110-10500 | NA |
| Calcium | ppm | ND | 60.4 | 19600-50000 | NA |
| Cerium | ppm | NA | NA | NA | NA |
| Cesium | ppm | NA | NA | NA | NA |
| Cobalt | ppm | 0.200-0.500 | NA | ND | NA |
| Chromium, Total | ppm | 13.7-16.7 | ND | 1010-19700 | NA |

## TABLE 2.7

## SOLAR EVAPORATION POND 207A
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

(continued)

| Compound | Units | 207A Liquid | | 207A Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| Chromium, Hexavalent | ppm | NA | NA | ND-1.0 | NA |
| Copper | ppm | 1.61-1.8 | ND | 425-1590 | NA |
| Germanium | ppm | NA | NA | NA | NA |
| Iron | ppm | 1.5-8.0 | ND | 3590-6900 | NA |
| Lead | ppm | ND | 0.004 | 65-455 | NA |
| Lithium | ppm | NA | 1.42 | NA | NA |
| Magnesium | ppm | ND | 121 | 6100-21000 | NA |
| Manganese | ppm | 0.095-0.115 | ND | 153-595 | NA |
| Mercury | ppm | ND-0.0002 | ND | 7.5-25 | NA |
| Molybdenum | ppm | NA | ND | NA | NA |
| Nickel | ppm | 1.9-2.0 | ND | 124-1320 | NA |
| Niobium | ppm | NA | NA | NA | NA |
| Phosphorours | ppm | NA | NA | NA | NA |
| Potassium | ppm | 13200-14300 | 376 | 50000-65300 | NA |
| Rubidium | ppm | NA | NA | NA | NA |
| Selenium | ppm | ND | 0.015 | ND | NA |
| Silicon | ppm | NA | 0.846 | NA | NA |
| Silver | ppm | NA | ND | 153-237 | NA |
| Sodium | ppm | 36300-42900 | 1610 | 130000-166000 | NA |
| Strontium | ppm | NA | 2.35 | NA | NA |
| Tantalum | ppm | NA | NA | NA | NA |
| Tellurium | ppm | NA | NA | NA | NA |
| Thallium | ppm | NA | ND | NA | NA |
| Thorium | ppm | NA | NA | NA | NA |
| Tin | ppm | 7-13 | ND | ND | NA |
| Titanium | ppm | NA | NA | NA | NA |

# TABLE 2.7

## SOLAR EVAPORATION POND 207A
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
### (continued)

| Compound | Units | 207 A Liquid 1984-1988 Range | 1991 Composite | 207A Sludge 1984-1988 Range | 1991 Composite |
|---|---|---|---|---|---|
| Tungsten | ppm | NA | NA | NA | NA |
| Vanadium | ppm | 0.10-0.20 | NA | NA | NA |
| Zirconium | ppm | NA | NA | NA | NA |
| Zinc | ppm | 0.62-0.78 | 0.028 | 227-595 | NA |
| VOLATILE ORGANICS | | | | | |
| Acetone | ppb | 100-260 | 3 | 5-4680 | NA |
| Methylene Chloride | ppb | ND | 5 | ND | NA |
| Tetrachloroethene | ppb | ND | ND | ND-1200 | NA |
| SEMIVOLATILE | | | | | |
| Acenaphthene | ppb | NA | ND | NA | NA |
| Bis(2-ethylhexyl) phthalate | ppb | NA | ND | ND-14900 | NA |
| 4-Chloro-3-methylphenol | ppb | NA | ND | NA | NA |
| 2-Chlorophenol | ppb | NA | ND | NA | NA |
| 1, 4-Dichlorobenzene | ppb | NA | ND | NA | NA |
| 2, 4-Dinitrotoluene | ppb | NA | ND | NA | NA |
| Di-n-butyl phthalate | ppb | NA | ND | ND-590 | NA |
| Fluoranthene | ppb | NA | ND | 161-1680 | NA |
| N-Nitroso-di-popylamine | ppb | NA | ND | NA | NA |
| Phenol | ppb | NA | ND | NA | NA |
| Phenols, Total | ppb | 13-35 | NA | ND-3300 | NA |
| Pyrene | ppb | NA | ND | NA | NA |
| 1,2,4-Trichlorobenzene | ppb | NA | ND | NA | NA |
| PESTICIDES/PCBs | | | | | |
| Atrazine | ppb | NA | 3.5 | NA | NA |
| Diazinon | ppb | NA | ND | NA | NA |
| Simazine | ppb | NA | ND | NA | NA |

**TABLE 2.7**

**SOLAR EVAPORATION POND 207A**
**SUMMARY OF LIQUID AND SLUDGE SAMPLE RESULTS**
(continued)

References:      Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

**TABLE 2.8**

**SOLAR EVAPORATION POND 207B (North)**
**SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**

| Compound | Units | 207 B (North) Liquid | | 207B (North) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| ANIONS | | | | | |
| Ammonia | ppm | NA | ND | NA | 102 |
| Bicarbonate | ppm | NA | ND | NA | ND |
| Carbonate | ppm | NA | ND | NA | ND |
| Chloride | ppm | NA | 147 | NA | 1910 |
| Cyanide, Total | ppm | NA | 37.8 | NA | ND |
| Fluoride | ppm | NA | ND | NA | ND |
| Nitrate, N | ppm | 212-1367 | 39 | NA | 600 |
| Nitrite | ppm | NA | ND | NA | 10 |
| Phosphate, Ortho | ppm | NA | ND | NA | 4 |
| Phosphate, Total | ppm | NA | 0.04 | NA | ND |
| Sulfate | ppm | NA | 155 | NA | ND |
| Sulfide | ppm | NA | ND | NA | 56 |
| TKN-N | ppm | NA | ND | NA | 1430 |
| RADIONUCLIDES | | | | | |
| Americium -241 | pCi/l | ND | 0.14 | NA | ND |
| Americium -241 | pCi/g | NA | NA | NA | NA |
| Plutonium -239 | pCi/l | ND | ND | NA | 2.2 |
| Plutonium -239 | pCi/g | NA | NA | NA | NA |
| Uranium -234 | pCi/l | 50-53 | 40 | NA | 13 |
| Uranium -234 | pCi/g | NA | NA | NA | NA |
| Uranium -235 | pCi/l | NA | 1.7 | NA | .0.4 |
| Uranium -235 | pCi/g | NA | NA | NA | NA |
| Uranium -238 | pCi/l | 31-33 | 26 | NA | 8.4 |
| Uranium -238 | pCi/g | NA | NA | NA | NA |

## TABLE 2.8

### SOLAR EVAPORATION POND 207B (North)
### SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
**(continued)**

| Compound | Units | 207 B (North) Liquid | | 207B (North) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| Uranium | pCi/l | NA | ND | NA | ND |
| Tritium | pCi/l | 1200-1300 | NA | NA | NA |
| Tritium | pCi/g | NA | NA | NA | NA |
| Gross Alpha | pCi/l | 13-323 | 59 | NA | 33 |
| Gross Beta | pCi/l | 5-200 | 110 | NA | 46 |
| MISCELLANEOUS | | | | | |
| Alkalinity, Total | ppm | NA | 75 | NA | 290 |
| Conductivity @25C | uMHOs | NA | 3380 | NA | 589 |
| Total Dissolved Solids | ppm | NA | 3200 | NA | NA |
| Total Organic Carbon | ppm | NA | 7.6 | NA | 11000 |
| Total Suspended Solids | % | NA | 18 | NA | 26 |
| pH | ppm | 7.5-9.6 | 8.5 | NA | 7.3 |
| METALS | | | | | |
| Aluminum | ppm | ND - 1.00 | ND | NA | 4140 |
| Antimony | ppm | ND | ND | NA | ND |
| Arsenic | ppm | ND | ND | NA | ND |
| Barium | ppm | ND - 0.22 | ND | NA | NA |
| Beryllium | ppm | ND - 0.06 | NA | NA | NA |
| Biosmuth | ppm | ND | ND | NA | ND |
| Boron | ppm | 0.09-0.31 | 0.173 | NA | ND |
| Cadmium | ppm | ND - 0.01 | ND | NA | 12 |
| Calcium | ppm | 20-290 | 189 | NA | 247000 |
| Cerium | ppm | ND | NA | NA | NA |
| Cesium | ppm | ND | NA | NA | NA |
| Cobalt | ppm | ND | NA | NA | NA |
| Chromium, Total | ppm | ND | ND | NA | 33 |

# TABLE 2.8

## SOLAR EVAPORATION POND 207B (North)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
### (continued)

| Compound | Units | 207 B (North) Liquid | | 207B (North) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| Chromium, Hexavalent | ppm | NA | NA | NA | NA |
| Copper | ppm | ND | ND | NA | ND |
| Germanium | ppm | ND | NA | NA | NA |
| Iron | ppm | ND -0.29 | ND | NA | 4530 |
| Lead | ppm | ND - 0.004 | ND | NA | 12 |
| Lithium | ppm | 0.37-6 | 0.332 | NA | ND |
| Magnesium | ppm | 66-120 | 79.3 | NA | 4670 |
| Manganese | ppm | ND-0.015 | ND | NA | 80 |
| Mercury | ppm | ND | ND | NA | ND |
| Molybdenum | ppm | ND-0.0069 | ND | NA | ND |
| Nickel | ppm | ND -0.05 | ND | NA | ND |
| Niobium | ppm | ND | NA | NA | NA |
| Phosphorours | ppm | ND | NA | NA | NA |
| Potassium | ppm | 56-120 | 58.8 | NA | ND |
| Rubidium | ppm | ND | NA | NA | NA |
| Selenium | ppm | ND -0.024 | 0.008 | NA | ND |
| Silicon | ppm | ND -5.6 | 1.02 | NA | 2670 |
| Silver | ppm | ND -0.082 | ND | NA | ND |
| Sodium | ppm | 363-820 | 403 | NA | ND |
| Strontium | ppm | 0.14-3.5 | 2.22 | NA | 692 |
| Tantalum | ppm | ND | NA | NA | NA |
| Tellurium | ppm | ND | NA | NA | NA |
| Thallium | ppm | ND | ND | NA | 7 |
| Thorium | ppm | ND | NA | NA | NA |
| Tin | ppm | ND | ND | NA | ND |
| Titanium | ppm | ND | NA | NA | NA |

# TABLE 2.8

## SOLAR EVAPORATION POND 207B (North)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

(continued)

| Compound | Units | 207 B (North) Liquid | | 207B (North) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1988 Range | 1991 Composite |
| Tungsten | ppm | ND | NA | NA | NA |
| Vanadium | ppm | ND | NA | NA | NA |
| Zirconium | ppm | ND | NA | NA | NA |
| Zinc | ppm | ND - 0.022 | 0.048 | NA | 101 |
| **VOLATILE ORGANICS** | | | | | |
| Acetone | ppb | ND | ND | NA | ND |
| Methylene Chloride | ppb | 19-71 | ND | NA | ND |
| Tetrachloroethene | ppb | ND | ND | NA | ND |
| **SEMIVOLATILE** | | | | | |
| Acenaphthene | ppb | NA | ND | NA | 4500 |
| Bis(2-ethylhexyl) phthalate | ppb | NA | ND | NA | NA |
| 4-Chloro-3-methylphenol | ppb | NA | ND | NA | 7900 |
| 2-Chlorophenol | ppb | NA | ND | NA | 7700 |
| 1, 4-Dichlorobenzene | ppb | NA | ND | NA | 4000 |
| 2, 4-Dinitrotoluene | ppb | NA | ND | NA | 3500 |
| Di-n-butyl phthalate | ppb | NA | ND | NA | ND |
| Fluoranthene | ppb | NA | ND | NA | ND |
| N-Nitroso-di-popylamine | ppb | NA | ND | NA | 3900 |
| Phenol | ppb | NA | ND | NA | 7400 |
| Phenols, Total | ppb | 3-46 | NA | NA | NA |
| Pyrene | ppb | NA | ND | NA | 4600 |
| 1,2,4-Trichlorobenzene | ppb | NA | ND | NA | 4300 |
| **PESTICIDES/PCBs** | | | | | |
| Atrazine | ppb | NA | 1.1 | NA | ND |
| Diazinon | ppb | NA | ND | NA | ND |
| Simazine | ppb | NA | ND | NA | ND |

**TABLE 2.8**

**SOLAR EVAPORATION POND 207B (NORTH)**
**SUMMARY OF LIQUID AND SLUDGE SAMPLE RESULTS**
(continued)

References:      Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
             Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

**TABLE 2.9**

**SOLAR EVAPORATION POND 207B (Center)**
**SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**

| Compound | Units | 207 B (Center) Liquid | | 207B (Center) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| ANIONS | | | | | |
| Ammonia | ppm | NA | 0.5 | NA | 135 |
| Bicarbonate | ppm | NA | ND | NA | ND |
| Carbonate | ppm | NA | 280 | NA | ND |
| Chloride | ppm | NA | 763 | NA | 11200 |
| Cyanide, Total | ppm | NA | 0.555 | NA | ND |
| Fluoride | ppm | NA | 73 | NA | ND |
| Nitrate, N | ppm | ND - 1220 | 1600 | NA | 13000 |
| Nitrite | ppm | NA | 75 | NA | 470 |
| Phosphate, Ortho | ppm | NA | ND | NA | 14 |
| Phosphate, Total | ppm | NA | 3.1 | NA | 2100 |
| Sulfate | ppm | NA | 736 | NA | 6950 |
| Sulfide | ppm | NA | ND | NA | ND |
| TKN-N | ppm | NA | ND | NA | 16700 |
| RADIONUCLIDES | | | | | |
| Americium -241 | pCi/l | NA | 5.5 | NA | ND |
| Americium -241 | pCi/g | NA | NA | NA | NA |
| Plutonium -239 | pCi/l | NA | 0.4 | NA | 5.1 |
| Plutonium -239 | pCi/g | NA | NA | NA | NA |
| Uranium -234 | pCi/l | NA | 780 | NA | 70 |
| Uranium -234 | pCi/g | NA | NA | NA | NA |
| Uranium -235 | pCi/l | NA | 36 | NA | 2.5 |
| Uranium -235 | pCi/g | NA | NA | NA | NA |
| Uranium -238 | pCi/l | NA | 900 | NA | 75 |
| Uranium -238 | pCi/g | NA | NA | NA | NA |

# TABLE 2.9

## SOLAR EVAPORATION POND 207B (Center)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 B (Center) Liquid | | 207B (Center) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Uranium | pCi/l | NA | ND | NA | ND |
| Tritium | pCi/l | NA | NA | NA | NA |
| Tritium | pCi/g | NA | NA | NA | NA |
| Gross Alpha | pCi/l | 4 - 2500 | 2400 | NA | 120 |
| Gross Beta | pCi/l | 8 -1500 | 3900 | NA | 380 |
| MISCELLANEOUS | | | | | |
| Alkalinity, Total | ppm | NA | 1000 | NA | 2700 |
| Conductivity @25C | uMHOs | NA | 1350 | NA | 3700 |
| Total Dissolved Solids | ppm | NA | 13000 | NA | ND |
| Total Organic Carbon | ppm | NA | 126 | NA | 22000 |
| Total Suspended Solids | % | NA | 15 | NA | 10 |
| pH | ppm | 7.3-11.3 | 9.1 | NA | 9.2 |
| METALS | | | | | |
| Aluminum | ppm | ND - 2.00 | ND | NA | 2350 |
| Antimony | ppm | ND | ND | NA | ND |
| Arsenic | ppm | ND | 0.014 | NA | ND |
| Barium | ppm | ND | ND | NA | ND |
| Beryllium | ppm | ND | ND | NA | ND |
| Biosmuth | ppm | ND | ND | NA | ND |
| Boron | ppm | 0.071-0.67 | 2.77 | NA | ND |
| Cadmium | ppm | ND - 0.01 | ND | NA | 108 |
| Calcium | ppm | 2.9-95 | 22.6 | NA | 108000 |
| Cerium | ppm | ND | NA | NA | NA |
| Cesium | ppm | ND - 0.35 | NA | NA | NA |
| Cobalt | ppm | ND | NA | NA | NA |
| Chromium, Total | ppm | ND | 0.094 | NA | 127 |

# TABLE 2.9

## SOLAR EVAPORATION POND 207B (Center)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 B (Center) Liquid | | 207B (Center) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Chromium, Hexavalent | ppm | NA | NA | NA | 97 |
| Copper | ppm | ND - 0.037 | 0.035 | NA | 96 |
| Germanium | ppm | ND | NA | NA | NA |
| Iron | ppm | ND - 0.2 | ND | NA | 2650 |
| Lead | ppm | ND - 0.002 | ND | NA | 13 |
| Lithium | ppm | 0.052 - 3.5 | 2.6 | NA | ND |
| Magnesium | ppm | 3.9- 91 | 181 | NA | 13700 |
| Manganese | ppm | ND - 0.022 | ND | NA | 208 |
| Mercury | ppm | ND | ND | NA | 2 |
| Molybdenum | ppm | 0.004 - 0.037 | ND | NA | ND |
| Nickel | ppm | ND -0.016 | ND | NA | ND |
| Niobium | ppm | ND | NA | NA | NA |
| Phosphorours | ppm | ND-0.2 | NA | NA | NA |
| Potassium | ppm | 30-110 | 729 | NA | ND |
| Rubidium | ppm | ND | NA | NA | NA |
| Selenium | ppm | ND-0.019 | ND | NA | ND |
| Silicon | ppm | 1.4 - 5.5 | 1.41 | NA | 2690 |
| Silver | ppm | ND-0.015 | ND | NA | ND |
| Sodium | ppm | 67-800 | 2440 | NA | 31300 |
| Strontium | ppm | 0.14 - 0.52 | 2.13 | NA | 848 |
| Tantalum | ppm | ND | NA | NA | NA |
| Tellurium | ppm | ND | NA | NA | NA |
| Thallium | ppm | ND | ND | NA | ND |
| Thorium | ppm | ND | NA | NA | ND |
| Tin | ppm | ND | 0.109 | NA | ND |
| Titanium | ppm | ND | NA | NA | NA |

## TABLE 2.9

## SOLAR EVAPORATION POND 207B (Center)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 B (Center) Liquid | | 207B (Center) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Tungsten | ppm | ND | NA | NA | NA |
| Vanadium | ppm | ND - 0.0081 | NA | NA | NA |
| Zirconium | ppm | ND - 0.004 | NA | NA | NA |
| Zinc | ppm | ND - 0.041 | ND | NA | 186 |
| VOLATILE ORGANICS | | | | | |
| Acetone | ppb | NA | ND | NA | ND |
| Methylene Chloride | ppb | NA | ND | NA | ND |
| Tetrachloroethene | ppb | NA | ND | NA | ND |
| SEMIVOLATILE | | | | | |
| Acenaphthene | ppb | NA | ND | NA | ND |
| Bis(2-ethylhexyl) phthalate | ppb | NA | ND | NA | ND |
| 4-Chloro-3-methylphenol | ppb | NA | ND | NA | ND |
| 2-Chlorophenol | ppb | NA | ND | NA | ND |
| 1, 4-Dichlorobenzene | ppb | NA | ND | NA | ND |
| 2, 4-Dinitrotoluene | ppb | NA | ND | NA | ND |
| Di-n-butyl phthalate | ppb | NA | ND | NA | ND |
| Fluoranthene | ppb | NA | ND | NA | ND |
| N-Nitroso-di-popylamine | ppb | NA | ND | NA | ND |
| Phenol | ppb | NA | ND | NA | ND |
| Phenols, Total | ppb | NA | NA | NA | NA |
| Pyrene | ppb | NA | ND | NA | ND |
| 1,2,4-Trichlorobenzene | ppb | NA | ND | NA | ND |
| PESTICIDES/PCBs | | | | | |
| Atrazine | ppb | NA | 9 | NA | ND |
| Diazinon | ppb | NA | ND | NA | ND |
| Simazine | ppb | NA | ND | NA | ND |

# TABLE 2.9

## SOLAR EVAPORATION POND 207B (CENTER)
## SUMMARY OF LIQUID AND SLUDGE SAMPLE RESULTS
(continued)

References:        Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

## TABLE 2.10

## SOLAR EVAPORATION POND 207B (South)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

| Compound | Units | 207 B (South) Liquid | | 207 B (South) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| ANIONS | | | | | |
| Ammonia | ppm | NA | 0.97 | NA | 256 |
| Bicarbonate | ppm | NA | ND | NA | ND |
| Carbonate | ppm | NA | 190 | NA | ND |
| Chloride | ppm | NA | 745 | NA | 11300 |
| Cyanide, Total | ppm | NA | 0.509 | NA | ND |
| Fluoride | ppm | NA | 72.5 | NA | ND |
| Nitrate, N | ppm | NA | 1800 | NA | 11000 |
| Nitrite | ppm | NA | 100 | NA | 860 |
| Phosphate, Ortho | ppm | NA | ND | NA | 23 |
| Phosphate, Total | ppm | NA | 2.6 | NA | 260 |
| Sulfate | ppm | NA | 784 | NA | 8530 |
| Sulfide | ppm | NA | 1 | NA | ND |
| TKN-N | ppm | NA | ND | NA | 12100 |
| RADIONUCLIDES | | | | | |
| Americium -241 | pCi/l | NA | 0.1 | NA | 2.4 |
| Americium -241 | pCi/g | NA | NA | NA | NA |
| Plutonium -239 | pCi/l | NA | 0.1 | NA | 1.9 |
| Plutonium -239 | pCi/g | NA | NA | NA | NA |
| Uranium -234 | pCi/l | NA | 760 | NA | 130 |
| Uranium -234 | pCi/g | NA | NA | NA | NA |
| Uranium -235 | pCi/l | NA | 31 | NA | 2.9 |
| Uranium -235 | pCi/g | NA | NA | NA | NA |
| Uranium -238 | pCi/l | NA | 870 | NA | 150 |
| Uranium -238 | pCi/g | NA | NA | NA | NA |

**TABLE 2.10**

## SOLAR EVAPORATION POND 207B (South)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

**(continued)**

| Compound | Units | 207 B (South) Liquid | | 207 B (South) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Uranium | pCi/l | NA | ND | NA | ND |
| Tritium | pCi/l | NA | NA | NA | NA |
| Tritium | pCi/g | NA | NA | NA | NA |
| Gross Alpha | pCi/l | NA | 1600 | NA | 150 |
| Gross Beta | pCi/l | NA | 2300 | NA | 530 |
| MISCELLANEOUS | | | | | |
| Alkalinity, Total | ppm | NA | 860 | NA | 3000 |
| Conductivity @25C | uMHOs | NA | 23000 | NA | NA |
| Total Dissolved Solids | ppm | NA | 16000 | NA | NA |
| Total Organic Carbon | ppm | NA | 297 | NA | 21000 |
| Total Suspended Solids | % | NA | 6 | NA | NA |
| pH | units | NA | 9.2 | NA | NA |
| METALS | | | | | |
| Aluminum | ppm | NA | ND | NA | 1870 |
| Antimony | ppm | NA | ND | NA | ND |
| Arsenic | ppm | NA | 0.0164 | NA | ND |
| Barium | ppm | NA | ND | NA | ND |
| Beryllium | ppm | NA | NA | NA | NA |
| Biosmuth | ppm | NA | ND | NA | ND |
| Boron | ppm | NA | 2.77 | NA | 138 |
| Cadmium | ppm | NA | ND | NA | 28 |
| Calcium | ppm | NA | 18.9 | NA | 124000 |
| Cerium | ppm | NA | NA | NA | NA |
| Cesium | ppm | NA | NA | NA | NA |
| Cobalt | ppm | NA | NA | NA | NA |
| Chromium, Total | ppm | NA | 0.0228 | NA | 30 |

# TABLE 2.10

## SOLAR EVAPORATION POND 207B (South)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 B (South) Liquid | | 207 B (South) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Chromium, Hexavalent | ppm | NA | NA | NA | NA |
| Copper | ppm | NA | 0.037 | NA | 95 |
| Germanium | ppm | NA | NA | NA | NA |
| Iron | ppm | NA | ND | NA | 2530 |
| Lead | ppm | NA | ND | NA | 9 |
| Lithium | ppm | NA | 2.67 | NA | ND |
| Magnesium | ppm | NA | 180 | NA | 9680 |
| Manganese | ppm | NA | 0.0182 | NA | 107 |
| Mercury | ppm | NA | 0.001 | NA | ND |
| Molybdenum | ppm | NA | 0.122 | NA | ND |
| Nickel | ppm | NA | 0.04 | NA | ND |
| Niobium | ppm | NA | NA | NA | NA |
| Phosphorours | ppm | NA | NA | NA | NA |
| Potassium | ppm | NA | 791 | NA | 7370 |
| Rubidium | ppm | NA | NA | NA | NA |
| Selenium | ppm | NA | ND | NA | ND |
| Silicon | ppm | NA | 0.952 | NA | 4320 |
| Silver | ppm | NA | ND | NA | ND |
| Sodium | ppm | NA | 2940 | NA | 24200 |
| Strontium | ppm | NA | 2.37 | NA | 720 |
| Tantalum | ppm | NA | NA | NA | NA |
| Tellurium | ppm | NA | NA | NA | NA |
| Thallium | ppm | NA | ND | NA | ND |
| Thorium | ppm | NA | NA | NA | NA |
| Tin | ppm | NA | NA | ND | ND |
| Titanium | ppm | NA | NA | NA | NA |

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# TABLE 2.10

## SOLAR EVAPORATION POND 207B (South)
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

**(continued)**

| Compound | Units | 207 B (South) Liquid | | 207 B (South) Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Tungsten | ppm | NA | NA | NA | NA |
| Vanadium | ppm | NA | NA | NA | NA |
| Zirconium | ppm | NA | NA | NA | NA |
| Zinc | ppm | NA | 0.037 | NA | 126 |
| VOLATILE ORGANICS | | | | | |
| Acetone | ppb | NA | ND | NA | ND |
| Methylene Chloride | ppb | NA | ND | NA | ND |
| Tetrachloroethene | ppb | NA | ND | NA | 130 |
| SEMIVOLATILE | | | | | |
| Acenaphthene | ppb | NA | ND | NA | ND |
| Bis(2-ethylhexyl) phthalate | ppb | NA | ND | NA | ND |
| 4-Chloro-3-methylphenol | ppb | NA | ND | NA | ND |
| 2-Chlorophenol | ppb | NA | ND | NA | ND |
| 1, 4-Dichlorobenzene | ppb | NA | ND | NA | ND |
| 2, 4-Dinitrotoluene | ppb | NA | ND | NA | ND |
| Di-n-butyl phthalate | ppb | NA | ND | NA | ND |
| Fluoranthene | ppb | NA | ND | NA | ND |
| N-Nitroso-di-popylamine | ppb | NA | ND | NA | ND |
| Phenol | ppb | NA | ND | NA | ND |
| Phenols, Total | ppb | NA | NA | NA | NA |
| Pyrene | ppb | NA | ND | NA | ND |
| 1,2,4-Trichlorobenzene | ppb | NA | ND | NA | ND |
| PESTICIDES/PCBs | | | | | |
| Atrazine | ppb | NA | 13 | NA | ND |
| Diazinon | ppb | NA | ND | NA | ND |
| Simazine | ppb | NA | ND | NA | ND |

# TABLE 2.10

## SOLAR EVAPORATION POND 207B (SOUTH)
## SUMMARY OF LIQUID AND SLUDGE SAMPLE RESULTS
(continued)

References:      Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

**TABLE 2.11**

**SOLAR EVAPORATION POND 207C**
**SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**

| Compound | Units | 207 C Liquid | | 207C Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| ANIONS | | | | | |
| Ammonia | ppm | NA | ND | NA | ND |
| Bicarbonate | ppm | NA | 4000 | NA | ND |
| Carbonate | ppm | NA | 25000 | NA | ND |
| Chloride | ppm | NA | 18300 | NA | 5360 |
| Cyanide, Total | ppm | ND-1.9 | 9650 | NA | 3200 |
| Fluoride | ppm | NA | ND | NA | 22800 |
| Nitrate, N | ppm | 0.4-21400 | 2600 | NA | 97000 |
| Nitrite | ppm | NA | 2500 | NA | 800 |
| Phosphate, Ortho | ppm | NA | 390 | NA | ND |
| Phosphate, Total | ppm | NA | 431 | NA | 1700 |
| Sulfate | ppm | NA | 12200 | NA | 110000 |
| Sulfide | ppm | NA | 10 | NA | ND |
| TKN-N | ppm | NA | ND | NA | ND |
| RADIONUCLIDES | | | | | |
| Americium -241 | pCi/l | ND-13000 | 8.6 | NA | 1.7 |
| Americium -241 | pCi/g | NA | NA | NA | NA |
| Plutonium -239 | pCi/l | 210-2100 | 670 | NA | 15 |
| Plutonium -239 | pCi/g | NA | NA | NA | NA |
| Uranium -234 | pCi/l | NA | 2600 | NA | 5.2 |
| Uranium -234 | pCi/g | NA | NA | NA | NA |
| Uranium -235 | pCi/l | NA | 120 | NA | 0.8 |
| Uranium -235 | pCi/g | NA | NA | NA | NA |
| Uranium -238 | pCi/l | NA | 3900 | NA | 31 |
| Uranium -238 | pCi/g | NA | NA | NA | NA |

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# TABLE 2.11

## SOLAR EVAPORATION POND 207C
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

**(continued)**

| Compound | Units | 207 C Liquid | | 207C Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Uranium | pCi/l | 1400-4000 | ND | NA | ND |
| Tritium | pCi/l | ND-6400 | ND | NA | NA |
| Tritium | pCi/g | NA | NA | NA | NA |
| Gross Alpha | pCi/l | 10000-46000 | 72000 | NA | 18 |
| Gross Beta | pCi/l | 405-44000 | 170000 | NA | 420 |
| MISCELLANEOUS | | | | | |
| Alkalinity, Total | ppm | NA | 45000 | NA | 24000 |
| Conductivity @25C | uMHOs | NA | 610000 | NA | NA |
| Total Dissolved Solids | ppm | 93900-175800 | 400000 | NA | NA |
| Total Organic Carbon | ppm | NA | 54.9 | NA | NA |
| Total Suspended Solids | % | NA | 76 | NA | NA |
| pH | units | 7.7-12.5 | 10.2 | NA | NA |
| METALS | | | | | |
| Aluminum | ppm | NA | ND | NA | 97 |
| Antimony | ppm | NA | ND | NA | ND |
| Arsenic | ppm | NA | ND | NA | ND |
| Barium | ppm | NA | ND | NA | ND |
| Beryllium | ppm | ND-0.6 | ND | NA | ND |
| Biosmuth | ppm | NA | ND | NA | ND |
| Boron | ppm | NA | 360 | NA | 117 |
| Cadmium | ppm | NA | 0.312 | NA | 6 |
| Calcium | ppm | NA | ND | NA | ND |
| Cerium | ppm | NA | NA | NA | NA |
| Cesium | ppm | NA | NA | NA | NA |
| Cobalt | ppm | NA | NA | NA | NA |
| Chromium, Total | ppm | NA | 2.36 | NA | 18 |

# TABLE 2.11

## SOLAR EVAPORATION POND 207C
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 C Liquid | | 207C Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Chromium, Hexavalent | ppm | NA | NA | NA | NA |
| Copper | ppm | NA | 6.79 | NA | 6 |
| Germanium | ppm | NA | NA | NA | NA |
| Iron | ppm | NA | ND | NA | 36 |
| Lead | ppm | NA | ND | NA | ND |
| Lithium | ppm | NA | ND | NA | 43 |
| Magnesium | ppm | NA | NA | NA | ND |
| Manganese | ppm | NA | ND | NA | ND |
| Mercury | ppm | NA | ND | NA | ND |
| Molybdenum | ppm | NA | ND | NA | ND |
| Nickel | ppm | NA | 5.09 | NA | ND |
| Niobium | ppm | NA | NA | NA | NA |
| Phosphorours | ppm | NA | NA | NA | NA |
| Potassium | ppm | NA | 78700 | NA | 273000 |
| Rubidium | ppm | NA | NA | NA | NA |
| Selenium | ppm | NA | ND | NA | ND |
| Silicon | ppm | NA | 30.1 | NA | 422 |
| Silver | ppm | NA | ND | NA | ND |
| Sodium | ppm | NA | 102000 | NA | 50900 |
| Strontium | ppm | NA | ND | NA | ND |
| Tantalum | ppm | NA | NA | NA | NA |
| Tellurium | ppm | NA | NA | NA | NA |
| Thallium | ppm | NA | ND | NA | ND |
| Thorium | ppm | NA | NA | NA | NA |
| Tin | ppm | NA | ND | NA | ND |
| Titanium | ppm | NA | NA | NA | NA |

## TABLE 2.11

## SOLAR EVAPORATION POND 207C
## SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

### (continued)

| Compound | Units | 207 C Liquid | | 207C Sludge | |
|---|---|---|---|---|---|
| | | 1984-1988 Range | 1991 Composite | 1984-1991 Range | 1991 Composite |
| Tungsten | ppm | NA | NA | NA | NA |
| Vanadium | ppm | NA | NA | NA | NA |
| Zirconium | ppm | NA | NA | NA | NA |
| Zinc | ppm | NA | ND | NA | 6 |
| VOLATILE ORGANICS | | | | | |
| Acetone | ppb | NA | 43 | NA | ND |
| Methylene Chloride | ppb | NA | ND | NA | ND |
| Tetrachloroethene | ppb | NA | ND | NA | ND |
| SEMIVOLATILE | | | | | |
| Acenaphthene | ppb | NA | ND | NA | ND |
| Bis(2-ethylhexyl) phthalate | ppb | NA | ND | NA | ND |
| 4-Chloro-3-methylphenol | ppb | NA | ND | NA | ND |
| 2-Chlorophenol | ppb | NA | ND | NA | ND |
| 1, 4-Dichlorobenzene | ppb | NA | ND | NA | ND |
| 2, 4-Dinitrotoluene | ppb | NA | ND | NA | ND |
| Di-n-butyl phthalate | ppb | NA | ND | NA | ND |
| Fluoranthene | ppb | NA | ND | NA | ND |
| N-Nitroso-di-popylamine | ppb | NA | ND | NA | ND |
| Phenol | ppb | NA | ND | NA | ND |
| Phenols, Total | ppb | 13-35 | NA | NA | NA |
| Pyrene | ppb | NA | ND | NA | ND |
| 1,2,4-Trichlorobenzene | ppb | NA | ND | NA | ND |
| PESTICIDES/PCBs | | | | | |
| Atrazine | ppb | NA | ND | NA | ND |
| Diazinon | ppb | NA | 2.8 | NA | ND |
| Simazine | ppb | NA | 7.5 | NA | ND |

# TABLE 2.11

## SOLAR EVAPORATION POND 207C
## SUMMARY OF LIQUID AND SLUDGE SAMPLE RESULTS
(continued)

References:     Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected